

Energy economics

growth, resources and policies

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致 读 者

本书内容中有“两个中国”、“一中一台”的荒谬提法，为便于有关人员参考，予以保留，请读者注意批判地使用有关资料。

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Preface

This book is intended as a contribution to energy studies. In many universities such studies form part of programmes in economics and social science, in engineering, or in management science, or they may be a central feature in courses on energy and the environment. Now and during the next few decades at least, energy problems, and recurrent crises in the way the world economy deals with these problems, must be expected to be an important factor in economic growth and technical change. An understanding of energy problems will therefore become essential for policy makers and for managers and advisers in both industry and government. In this book, the separate components of the energy system are described from a variety of viewpoints – economic, technical, social and environmental – but their interdependence is an essential feature.

We have written the book in a form which is accessible to the non-specialist. It is not an attempt to explain energy economics to trained engineers, or engineering science to those with degrees in economics. But it is not a 'chatty book', and we have tried to include all the hard facts and main steps in the analyses and arguments necessary to bring students, and an informed public outside the universities, towards the frontiers of knowledge in a complex of inter-related disciplines.

The book is structured in five parts, beginning with a discussion of the economics and technology of energy demand, and continuing in part two with a description of the main supply factors for hydro-carbons, nuclear energy and renewable energy resources. Part three is concerned with the market for energy, the structure of costs and prices, and the way in which the market is brought into balance. Part four considers the world energy outlook, taking account of the essential uncertainties of energy forecasting, and discusses energy prospects for different world regions. In the concluding chapters, energy policy issues are examined to illustrate the objectives, problems and constraints that arise, both within countries and between countries, in tackling the problems of obtaining and distributing energy resources.

Energy problems have a physical basis in the changing availability of energy

resources – particularly oil – but they are magnified by anticipation or delay and changed by economic, social and political responses so that they become much more serious than would have been expected from the underlying resource situation alone. This makes the magnitude of future energy crises as uncertain as their timing or frequency, but it underlines the important role that could be played by successful energy policies. The conflict of policies is well illustrated by the dramatic changes in world oil prices in recent years and the attempts by governments in some consumer countries to shield their voters from the impact of these changes. On world oil prices we have taken a deliberately undogmatic position. There are those – possibly more in North America than elsewhere – who regard the dizzy rise in the oil price in the last seven years as evidence of only one event – the cartelization of the world oil market by the OPEC powers, possibly assisted to some extent by some of the larger oil companies. Other observers, including both Europeans and many in the Middle East, see the rise in the oil price as the inevitable consequence of shortages foreseen in the closing years of this century and the opening decades of next, possibly assisted by poorly timed purchases to increase oil stocks in consumer countries. It would be pleasant for the authors if they could claim to have reconciled the two approaches or viewpoints, but that is never completely possible. We certainly see technical forces influencing the oil price – changes in the pattern of supply and demand – that are separate from and additional to changing trends in market dominance. However, perceptions and attitudes, as well as the distribution of resources and institutional structures, are an important component of energy policies. We hope that this book will help towards an understanding of the problems and difficulties that policies seek to resolve.

In writing a book like this the authors must draw freely on the work of others. Where the source of the information is in written form, we hope that we have always made proper acknowledgement in the text; where our ideas and inspiration have been borrowed in the normal course of informal discussion, academic contact or joint endeavour, public or private, acknowledgement is more difficult. There is now an international community of energy experts, who meet together fruitfully and frequently, and we gratefully acknowledge meetings and discussions arranged by the World Energy Conference, the Workshop on Alternative Energy Strategies, the Organisation of Arab Petroleum Exporting Countries, the Organisation of Latin American Departments of Energy, the International Energy Agency, the International Association of Energy Economists, the UK Science Research Council and the Social Science Research Council, the Oxford Energy Seminar and numerous energy meetings in Cambridge.

We are indebted to many individuals both through personal discussions and through colleagues in their organisations, though we hasten to add that in energy matters there is rarely any consensus and they are by no means responsible for our views and conclusions expressed in this book. We wish to express our thanks to: Sir

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Introduction

1.1 Economics of energy

The economics of energy are concerned with the availability of energy resources and their relation to economic activity. The industrialised world is now in the early and uncertain stages of a lengthy period of transition from low cost oil and natural gas to higher cost alternatives. The developing world will provide an increasingly important fraction of world energy demand and its economic growth will be influenced and complicated by increasing competition for world energy resources. A smooth transition by the industrialised world and equitable growth in the developing world will be disturbed or frustrated by energy shortages, and these, through the coupling of the energy system, will affect almost every aspect of economic activity.

Energy is not a single commodity; there is scope for substituting one form of energy for another provided the costs can be met. Such substitution involves the cost of diversion of other resources, manpower and skills, and also requires time to achieve. The lead times for a transition to new energy sources or carriers vary widely and are generally much larger for higher cost than for lower cost supplies. Though cheap natural gas and low priced oil could in the past rapidly penetrate the market for fuel and displace coal, the transition back to coal will not come so easily or quickly. This is partly due to the change in scale, since the world energy demand is now two or three times its level when coal was the dominant fuel, and partly due to handling problems in the mining, transportation and utilisation of coal. However, the main problems of transition arise from the changed character of the demand for different forms of energy associated with changing life styles and rising standards of living.

The personal mobility provided by automobiles has become an entrenched characteristic of society in developed countries, and the rapid growth in automobile ownership in developing countries reinforces the view that world energy demand for transport will continue to rise. The average yearly finding rate for world oil reserves has been less than total consumption for some years, and if this continues it is inevitable on resource grounds alone that production from conventional sources of oil will eventually decline. However, oil conservation policies in producer countries are likely to be more severe than technical limitations to supply. Thus on average there may be very little increase above current world oil production, and

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there is the ever present spectre of sudden shortages due to disturbances or political change in major producing areas. Automobiles cannot conveniently be powered by coal; the alternatives of providing synthetic gasoline or diesel oil from coal are expensive and it would take a long time for the production of quantities that could take a large share of the market. These facts and the high priority attached by most societies to road and air transport suggests that their share of world oil supply is likely to rise significantly.

The petrochemicals industry of North America is already in transition from the use of natural gas or natural gas liquids (light hydrocarbons produced with natural gas but liquid at normal temperature and pressure) to the wider use of oil. Oil is likely to remain its preferred fuel until the price rises to the level of synthetic oil from coal, at which point petrochemicals could be produced in conjunction with synthetic gasoline or diesel oil for road transport. In the Middle East, however, the large quantities of gas associated with oil production and the large reserves of natural gas, together with the high cost of transporting it, will lead to the development and continued expansion of a petrochemicals industry based on natural gas, though the mix of products from that industry will be influenced by the relatively high cost of transporting them to the major markets. These products may include substantial quantities of methanol or gasoline to supplement road transport fuel derived from oil. Over 50 per cent of world oil production and most of the gas production is used to provide heat for industry and in buildings or dwellings. Much of this is low grade heat (i.e. less than 100°C), but it is mainly used in households or commerce where convenience is a dominant consideration. If oil and natural gas supplies to developed countries decline, an increased demand would be expected for synthetic gas or electricity, except in sectors or markets where bulk steam raising is required and coal is readily available, or in specialist markets such as blast furnaces for the reduction of iron ore.

Estimates of future world demand for different forms of energy (coal or oil products, natural or synthetic gas, and electricity) depend strongly on assumptions about future economic growth. However, even with relatively low world growth, and with plausible assumptions about energy conservation or improved efficiencies in its use, it is difficult to see how there can be a balance between projections of energy demand and energy supply, unless the supply of fossil fuels follows a path that most observers would regard as optimistic and unless also there was a substantial component of supply from nuclear power (WAES, 1977a and World Energy Conference, 1978b). The relationship between energy demand and economic growth, and the impact on economic activity of a potential or actual scarcity of energy, is one of the important subjects considered in this book.

The relation between the economics and technology of energy provides the central theme of the book. The separate components of the energy system are described from a variety of viewpoints – economic, technical, social and environmental – but the interdependence of these components is an essential feature of the

Introduction

energy system. The resulting energy problems and opportunities vary widely between different world regions and between countries. Although energy policies, like economic policies, are determined on a national basis, few countries can insulate themselves from a crisis in the world energy system. Investment and trade in energy supplies form so key a component of economic activity that no satisfactory economic policy can ignore the requirements of energy policies nor the potential political or social consequences of a scarcity of energy.

The time scales that need to be considered in formulating energy policies are an order of magnitude longer than those commonly considered for economic policies, being measured in decades rather than years. The reader may reasonably take the view that no-one can foresee the future energy situation for decades into the future. It is precisely this recognition of uncertainty that should play a major role in energy planning. Policies and strategies need to be designed to remain robust under a variety of alternative futures. The assessment of alternative energy strategies in terms of costs and risk avoidance is an essential part of planning under uncertainty. *Some features of possible futures may seem more probable than others, but an unlikely future that involves severe penalties may demand planning to reduce the risk of it occurring or to reduce those penalties provided the cost of insurance is not too high.* The assessment of costs and penalties as well as potential risks is likely to be more an art than a science in all but the simplest cases, but this does not absolve planners from the duty of careful analysis, including the assessment of environmental and general social costs and risks. The indirect penalties of lower economic growth may well outweigh the direct costs of an energy scarcity, and it may also be important to examine different effects on economic growth and employment in different parts of the world and in different sections of society. It is hoped that this book will help reveal some of the problems that may arise, and assist in providing methods for approaching their solution.

1.2 Analytical framework

The intention of this book is to provide an integrated account and analysis of the economics of energy. It is integrated in several senses: firstly, through a combined and coordinated account of both the economics and the technology of energy; secondly, through discussion of the demand and supply balances for various forms of energy; thirdly, through the global character of energy problems – no country is an island unto itself; and fourthly, through the impact of energy on global and national economic activity. Energy problems taken alone may appear to yield to simple analysis but, when considered in relation to the constraints and influences of the economic, social and political system, they assume a different and more complex character.

It is against this background of the complex relations between energy and other factors that energy problems should ultimately be analysed. However, in develop-

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ing this analysis it is often convenient to present simple pictures and use idealised models. Such pictures or models are valuable both as a means of instruction and to clarify part of a problem. It may be splendid to consider energy problems in all their complexity and confusion, but the only model that would wholly satisfy this objective is the real world. The purpose of analysis is to provide a framework within which some of the more complex problems of energy strategy may be discussed.

The book is planned in five parts. First, we consider *energy demand*, examining the extent to which it may be possible to foresee changes in the long standing relation between gross domestic product (GDP) and the use of energy. If, in fact, this relationship is enduring, energy demand is bound to go on increasing over several more decades if economic growth is maintained in that period. The technological structure of energy demand in relation to economic activity is central to this question and forms an important chapter in this part of the book.

In the second part we go on to the *supply factors* for hydrocarbons, for nuclear energy, and for renewable energy resources. One of the critical factors in many of the problems foreseen is the future supply of oil. Ultimately this depends on the geological structure of world reserves and resources, but its potential depends strongly on social, economic and political factors affecting exploration and development of oil reserves. These wider factors also play an important role in their influence on interfuel substitution and the acceptability of alternatives to oil. This part of the book therefore includes a chapter on 'externalities', the social, technical and environmental costs of different forms of energy supply which are often considered in isolation. This chapter seeks to find an appropriate perspective from which to view these costs so that one can more readily perceive the choices that may need to be made.

Next, in part three of the book, we turn to the *market* for energy, examine the ways in which supply and demand balance, and consider the extraordinarily complex structure of costs and prices. This structure is of great importance in contributing to the inelasticity of demand for some forms of energy. The investment and lead time requirements for the production, transport and conversion of energy strongly affect costs and prices, and the need for long-term planning. High investment costs and long lead times may inhibit risk-taking for the development of new sources of energy or conversion facilities; they also characterize the technology for energy conservation, where investment is often required to achieve greater efficiencies.

In the international market, the availability of low cost oil reduced the importance of indigenous energy supplies, particularly during the period 1950-73. However, the increased price for oil in the post-1973 period has led at least to a theoretical awareness of the importance of indigenous supplies, both for security and for reducing balance of payments problems. Trade in alternatives to oil, such as liquefied natural gas (LNG), coal and uranium, poses different problems - environmental, social and economic in character. For some of these problems the

world is like a village with common social responses and environmental preferences, but for others – particularly when economic growth is in question – there may be a divergence of views between rich and poor, developed countries and developing countries.

Part four of the book is concerned with *energy prospects*. The future is uncertain and long lead times (i.e. long times between inception and completion of energy projects) require decisions that affect long-term prospects. Long lead times may be anathema to politicians for whom theoretical benefits to future generations may seem unrelated to the realities of power or the present needs of their electors. However, for energy planners or forecasters, these long lead times have a major influence in reducing uncertainty. All forecasts are conditional – conditional on the assumptions from which they are derived. They are dependent on assumptions about future economic growth, but once these economic assumptions are made, the lead times for change in the supply, conversion, or substitution of different fuels have the effect of reducing the range of uncertainty in projections of possible futures (the development of scenarios). Interfuel substitution or conservation is affected by relative prices, government policies and social preferences. Scenarios are presented that illustrate some of the problems that may arise and the alternative energy strategies that could be adopted by different nations or groups of nations to reduce the difficulties that they may perceive.

The final part of the book takes the discussion of energy strategies into the wider context of *energy policies* and economic objectives. National decisions on energy supply are influenced by indigenous energy resources. Greater adoption of resource conservation policies may become important in a period of rising energy prices, while uncertainties due to national expectations for producer incomes or tax revenues may inhibit development of new resources. In particular, national views on resource conservation or environmental protection may restrict exports of coal and hence limit its international trade. National policies on energy prices and taxes lead to wide variations in prices to the consumer, they affect the elasticity of response to a changed world energy picture and they affect the technical efficiencies with which energy is used. Instruments for government intervention in energy demand, other than through the price mechanism, vary widely between different countries and cultures, and their adoption may be delayed through institutional difficulties or simply because governments have more urgent priorities.

The importance of a margin of potential supply of energy over actual demand was illustrated by the Suez crisis in 1957 and the Arab oil embargo in 1973. Oil imports will not be available for all countries to balance their expected projections of demand and supply to the year 2000 unless world oil discoveries are far greater than can reasonably be expected. National planning for economic growth and energy demand requires an awareness of the global constraints and the related uncertainties. Energy policies in the developed regions may be influenced by the common objective of further economic growth, or by common constraints due to