energy economics, demand management and conservation policy

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Demand Management and Conservation Policy

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FOREWORD

Two successive oil crises, in 1973 and 1979, revealed the energy vulnerability of a great many countries, both rich and poor. With their economies long organized in relation to low oil prices, these countries now find, under the weight of excessive and sometimes unbearable oil import bills, that their energy supply strategies are failing them. Only hindsight can justify talk of improvidence.

The only alternative is for these countries to endeavor to redesign their energy economies within the shortest possible time, focusing on resources and systems that cost less and are more reliable. In the process of doing so, however, they find themselves coming up against forces of inertia within the energy sector itself. Although it is supremely capable of reducing unit costs by combining economies of scale with standardization, this sector lacks flexibility when it comes to converting to entirely new processes, on both the supply and demand sides. It takes time to optimize performance in fresh fields—time to bring innovation to maturity, to convert energy-generation and supply systems, to instill new behavioral attitudes, and to write off existing energy-inefficient equipment. These are all fairly irreducible time lags, each of which delays the substitution process.

In this context, the least malleable link in the energy chain is to be found on the demand side, which involves the greater part of the capital invested in the existing system, although it is less obtrusive as a result of being spread among an enormous and varied mass of energy end-users. The ability to channel the trend of demand in such a manner that both the individual and the general interest are safeguarded as far as possible is thus a matter of great importance.

The foremost merit of this book by Mohan Munasinghe and Gunter Schramm is that it provokes a fundamental reappraisal of all the aspects of this question—first, by identifying the demand factor within the overall view of the energy economy (Chapter 2); second, by widening the field of investigation to take in the other major links in the energy chain represented by reserves and production facilities, and last, by analyzing demand within the framework of overall energy policy (Chapter 3).

The authors stress that pricing policy is the main instrument of demand management (Chapters 4 and 5). They then proceed to explain how long-run

marginal cost is the practical pricing basis most conducive to reconciling individual consumer options with the optimization of net benefits to society as a whole. Cost transparency, a clear distinction between economic efficiency and technical constraints on the one hand and social objectives on the other, and compatible management and planning policies are some of the undoubted advantages to be derived from this approach—an approach now being adopted by many countries.

Furthermore, the oil crisis made it plain that priority could and should be awarded to energy-saving measures—the most logical way to check any rise in consumption. When assessing achievements in this regard, however, due allowance must be made for the negative effects of a global economic recession on energy consumption, which have tended to reinforce conservation-oriented policies. We must also remember that reduced consumption in terms of calories alone cannot be a policy target and that the very concept of energy saving has different weight and meaning depending on whether the countries we consider are industrialized or developing (Chapter 6).

What then remains is to place all these factors in a proper perspective, evaluate as accurately as possible the economic and financial consequences of errors of calculation and projection, and highlight the close interrelationship between supply and demand (Chapters 7 and 8). Such considerations make it especially welcome that the authors devote the second part of their book to a review of country case studies that tests the theory against actual experience (Chapters 9 to 13).

Mohan Munasinghe and Gunter Schramm unfold before us a wide and promising field of reflection. They have combined the intellectual rigor of the economist with a rich store of personal experience to produce a most lucid, rewarding, and up-to-date exposition of their subject.

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PREFACE

The content of this book reflects our cumulative experiences and involvement with energy policy issues in many parts of the world, spanning a period of almost two decades—from the balmy pre-oil crisis days of falling real energy prices and emerging environmental concerns, to the massive dislocations following the 1973 and 1979/80 oil price shocks and their aftermaths. As this volume goes to press, once again world energy markets are in disequilibrium, with gleeful predictions by some that oil prices may fall by as much as a third or more compared to 1982 price levels. Whatever actually happens in the short run, however—and the short run may well extend for several years—it is our view that the real price of petroleum resources will tend to increase over time, gradually approaching the levels determined by the costs of replacements such as shale oil, heavy oil and tar sands extraction, or coal liquefaction. Whether these levels will be reached well before or shortly after the turn of this century is uncertain, but it is inevitable that this situation will eventually occur, given a gradually expanding world economy and limited and decreasing petroleum resources. Hence, in our view, short-term fluctuations in prices should not be taken as a reliable guideline for long-term policy decisions.

During the past decade of turbulent energy prices, many studies on energy policy have been published. Although early ones focused mainly on regulatory issues, later ones reflected the increasing concerns about environmental problems. The first oil price shock in 1973 resulted in a plethora of doomsday scenarios that equated the perceived finiteness of depletable resources with the unsustainability and decline of modern civilization as we know it. In these forecasts, energy use and alleged misuse played a prominent part. Energy consumption patterns were initially analyzed in terms of potential energy savings on a strictly technical basis, usually invoking the first and second law of thermodynamics, but forgetting that conservation measures, too, involve costs in terms of other economic resources. Other studies attempted to analyze existing consumption patterns on the basis of statistical comparisons of aggregate energy to GDP ratios and similar input-output relationships. From them, for a while, emerged a tendency to summarily condemn those countries whose ratios were higher than those of others as "energy wasters." What these studies con-

veniently overlooked, however, was that energy is but one input among others and that relative costs and prices in the past have shaped the interrelationship between different inputs and outputs and have also determined the location of energy intensive activities and industries. Instead, what is needed for drawing conclusions about energy "waste" are studies of these inter-relationships at the micro-level. At the same time, macro-economic changes that could have had a major effect on the structure and use of energy were not given sufficient attention in these early studies. Some of them concentrated on the analysis of energy supply, often grossly neglecting other aspects, especially potential changes in demand. In our view, most of them made at least some contribution to the overall issues of energy planning and policy analysis even if many suffered from the partial nature of their analysis and a lack of integration of all relevant economic, technological, physical, and socio-political factors. This lack of integration is something that we have tried to avoid in our analysis.

The book has been written for the use of a broad range of persons involved in energy sector work, including energy planners and policymakers, economists, other specialists, consultants, teachers, and researchers, and advanced undergraduates as well as graduate-level students. In order to address such a wide audience, we have made a deliberate attempt to avoid the use of economic jargon as much as possible. Where appropriate, mathematical derivations have been placed in technical appendices and the results of our findings explained as simply as possible in the main text, often using diagrammatic expositions.

The first eight chapters present the necessary background information and analytical base. The following five consist of a series of case studies that apply the principles developed to real-world situations. A special characteristic of all of these case studies is that one or both of us were closely involved in the original fieldwork and subsequent analysis.

The writing of this book has spanned several years. Although this imposed a special burden on both of us and our families, it had the advantage that we could observe the dynamics of energy supply-demand interactions over time, in a given location, and for a given use. This ongoing process of observation has provided us with important insights into the dynamics of change and the effects of bottlenecks caused by lack of consumer comprehension, lock-in effects, and delayed policy responses.

In developing our analysis and writing this book, we have benefited from the advice of many of our friends and colleagues around the world. We are grateful to Marcel Boiteux, distinguished 'father' of modern marginal cost pricing, for having contributed the Foreword. Special thanks are due to Romesh Dias-Bandaranaike of IFC, Inc., and Martin J. Beckmann of Brown University, who helped develop, respectively, the mathematical models of electricity demand and the optimal user cost that are contained in the Annex to Chapter 13 and Annex 4.2. A close friend and colleague, Jeremy Warford, was instrumental

in stimulating our interest in the issues of energy pricing and demand analysis. Without his encouragement, this book would not have been undertaken. Michael G. Webb and Robert Pindyck read earlier versions of the manuscript and made many valuable suggestions for its improvement. At the World Bank, we want to thank a large number of colleagues and friends whose insights and comments have contributed much to our own understanding of energy issues. Among them are Yves Rovani, Richard Sheehan, Robert Sadove, D. C. Rao, James Fish, Richard Dosik, DeAnne Julius, David Hughart, Trevor Byer, Anwer Malik, Dennis Anderson, Karl Jechoutek, Ibrahim Elwan, Ernie Terrado, Fernando Manibog, Edwin Moore, Pierre Moulin, and Edward Minnig.

Since its inception in 1978, several hundred developing-country officials and fellow lecturers who participated in the USAID-sponsored energy management training program at Stonybrook have been exposed to and helped to clarify many of the concepts presented here. Among them, we would like to mention Robert Nathans, Peter Meier, Romir Chatterjee, Gerhard Tschannerl, David Jhirad, Vinod Mubayi, and Owew Carroll. At the University of Michigan, Kenneth Shapiro, Richard Porter, and Harvey Brazer all contributed, directly or indirectly, to the basic ideas incorporated in this volume. The members of three successive graduate seminars on energy economics at the University of Michigan worked their way through preliminary drafts and made many useful suggestions for improvements and clarification. Special thanks are due to Dale Avery, Theodore Graham-Tomasi, Enrique Crousillat, and Bruce DenUyl for their insightful comments and suggestions. Others we wish to thank include Jean-Romain Frisch, Blair T. Bower, Marc Ross, Roy J. Piggott, Robert Bakely, Jayant Madhab, Barin Ganguli, Shyam Rungta, V. V. Desai, Corazon Siddayao, Gail R. Wilensky, Tilak Siyambalapitiya, and K. D. P. Gunatilaka. Betty Manoulian typed many successive drafts of the volume and remained cheerful as always. Last, but not least, we want to thank our respective families—Sria, Anusha, and Ranjiva Munasinghe and Heidi, Eileen, and Barbara Schramm—for their patience, understanding and unstinting support.

Mohan Munasinghe
Gunter Schramm

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Part A
Theory and Methodology

1
Introduction and Overview

The rapid increases in energy prices in the 1970s have clearly indicated that the era of cheap and abundant energy, especially oil, is over. The cost of energy is now becoming increasingly significant relative to the costs of other factor inputs such as capital, labor, and land. The critical dependence of modern economies on energy in various forms underlines the need for effective development and use of scarce energy resources. The intricate links between energy and the different sectors of the economy, as well as the interactions among the various forms of energy, need to be carefully examined within a disaggregate but integrated framework. The application of rational economic analysis will improve the efficiency of investment decisions and pricing policy in the energy area. Even small improvements can have a significant beneficial impact, given the large investment needs and consumer expenditures on energy.

Energy use permeates every sector of the economy. Governments generally seek to ensure that the cheapest energy sources are available in sufficient quantities to meet the future needs of the economy and maximize the welfare of citizens. The energy crises of the 1970s have shown that when demand for energy exceeds supply, rapid price rises and economic dislocations occur, especially in the short run when the economy is unable to adjust smoothly to the new situation. Energy planning has therefore emerged as an important discipline that seeks to achieve the best balance between energy and other inputs such as capital and labor, and to match the uses and availabilities of different types of energy, such as oil, coal, and electricity in various uses, including industry, transportation, and households.

Actual or potential imbalances that result when energy demand exceeds supply can be avoided by either augmenting supply or by reducing demand or both. These two options may be broadly labeled supply and demand management respectively. More emphasis has been placed in the past on increasing supply, especially through the development of new and higher cost energy sources or by the application of more advanced technologies to existing resources. This book seeks to examine the policy options available to manage demand. The achievement of desirable energy conservation goals fall within this category. Supply management and investment planning issues are also

treated here to the extent that they influence demand, since demand and supply are often closely interrelated.

There are, of course, many uncertainties concerning the future availability and prices of different fuels, worldwide. However, the decade of the 1970s has shown that future energy costs will be higher relative to the costs of other goods and services than in earlier years. A major objective of all countries in the next decade will be the adjustment of their economies to higher energy prices. Thus demand management and conservation will be an important theme for some time to come, and there is good evidence to indicate that additional resources devoted to this effort are likely to be more cost effective, at least initially, than funds spent on merely increasing energy supply.

Chapter 1 continues with a summary of the other chapters in this book followed by a brief history of commercial energy use. It then explores the macroeconomic impacts of increased energy costs including the direct effects via the balance of payments, and reduced real incomes, as well as dynamic effects such as inflation, recession, and reduced GNP, investment, and employment. A special discussion of the developing country situation is provided.

1.1 SUMMARY OF THE BOOK

The rest of Chapter 1 begins with a brief history of energy use. In ancient times, human beings progressed from the use of their own muscle power to the harnessing of the energy of other animals such as horses and cattle. Since the industrial revolution, the use of machines and direct conversion of inanimate forms of energy for production has developed rapidly and resulted in high rates of economic growth and output.

Wood is the earliest and most common form of inanimate energy used by man; the practice dates back to the discovery of fire in prehistoric times. Fuelwood has also been used in manufacturing for many thousands of years. Next, the dominance of coal in industry developed during the industrial revolution in the 18th century, starting in Britain. Since the early 20th century, petroleum products have become increasingly important, particularly for transportation. Electricity, whether produced from hydro, oil, coal, or nuclear has also become a dominant and convenient form of energy in the modern economies of the 20th century.

Chapter 1 continues with an explanation of why modern industrialized or developing societies could not function without the use of large quantities of inanimate energy. In fact, the history of economic development is to a very large degree the history of the increasing use and substitution of inaminate for human or animal energy. The correlation between per capita energy use and real income per capita throughout the world is striking. On an aggregate basis, higher energy use implies higher income and vice versa. It is only at a much

more disaggregated level that significant variations in this general relationship become apparent.

While large-scale energy use is absolutely essential for the functioning of modern economies, the overall costs of energy relative to the total value of output is still modest, rarely exceeding 10% of total GNP even in the most energy-intensive countries of the world. Analyzed on an activity by activity basis, the cost of energy relative to the value of output of a given industry or process is less, usually amounting to only about 1–3% of the value of output, although energy costs may be in excess of 50% for a few energy-intensive production processes.

However, while the costs of energy relative to the value of output are small, in terms of foreign exchange balances the drastic increases in world prices for petroleum products in the 1970s have resulted in major dislocations for most petroleum importing countries. In 1978, for example, (prior to the more than 100% increase in world petroleum prices in 1979/80) a number of developed as well as developing countries spent close to 50% of their total income from exports on energy imports alone. If relative prices for petroleum products keep rising, by 1990 some of them may be forced to spend close to 100%. These increased costs of energy imports have led to a dangerous increase in the external debt burden of many energy-importing countries, and it is forcing some of them to curtail other essential imports.

Generally, the increases in energy costs have had adverse impacts on the economies of practically all countries, except those of the oil exporters, in terms of reduced growth rates and output, employment, and personal incomes. The direct effects of the energy crisis can be analyzed in an essentially static framework, and include the worsening of balance-of-payments mentioned earlier, as well as a fall in real income. Even if the level of gross national product is unaffected, more resources will have to be diverted to pay for energy and therefore less output will be available for domestic consumption and investment. These effects will be milder, the greater and more rapid the substitution possibilities between energy and other inputs to production. The dynamic impact of energy price increase occurs when the economy tries to adjust to a price shock. Rigidities in the economy and resistance to the necessary fall in real wages and prices of most other goods can lead to spiraling wage-price inflation. As workers fight to maintain real wages, employment will decline with a consequent loss of output. Finally, investment and economic growth will also fall off following a major energy price increase, because of uncertainty in the market regarding costs, interest rates, and profits, and the complementarity between capital and energy in the short run.

Such effects are evident in the performance of most economies following the 1973 oil price increase. Thus the OECD group of industrialized countries experienced sudden spiraling wage-price inflation (except for Germany), reduced

output, and recession during the 1973–1975 period.[1] In the oil importing developing countries (OIDCs), there has been a tendency to borrow heavily from external sources to tide over the initial shock. This is reasonable since in the short-run the economy is most inflexible to the energy price increase and foreign exchange is scarcest. Early borrowing is therefore made against subsequent periods when the economy has more time to adjust through energy substitution and other energy management policies. These macroeconomic effects of an increase in the costs of energy are analyzed more fully later in this chapter.

A major problem for the OIDCs is the increasing foreign debt service burden and their declining credit-worthiness as oil prices continue to increase. Improved mechanisms for recycling petrodollars and providing financial resources to these countries from the oil exporters, developed countries and multilateral aid agencies will have to be developed for the OIDCs to meet their increasing energy needs for economic growth and development. In general, the oil importing countries will need to finance massive investments for developing alternative energy sources, and for implementing energy conservation policies, to prevent catastrophic increases in their oil import bills.

Chapter 2 seeks to introduce the reader to the principal sources and uses of energy. While it has become customary to talk about energy as if it represented a homogenous commodity, this is inaccurate. Energy supplies come in many different forms. In most cases they have to be tailored precisely to specific uses. Petroleum products, for example, are divided into many different products, ranging from liquid petroleum gases (LPG) to gasoline, diesel fuels, kerosene, jet fuels, and various grades of fuel oils. All of these are designed for rather specific uses, and are not easily interchangeable with each other. Natural gas and coal are largely used as boiler and furnace fuels. Electricity is the major source of lighting, of mechanical energy for stationary uses, and of telecommunication equipment, as well as the energy source for electrochemical and electrosmelting processes. Electricity itself, in turn, is produced from other energy sources such as petroleum, natural gas, coal, or nuclear through the intermediary of high pressure steam turbines, gas turbines, internal combustion engines, or water-driven hydraulic turbines. Natural gas, petroleum products, coal, wood, charcoal, and biomass residues are the major sources of household and commercial energy for heating, cooking, and cooling. The lighter petroleum products are the almost exclusive fuels for independent transport equipment (e.g., airplanes, cars, trucks, ships, and railroad engines). Wood and other

[1]The 24 member countries of the OECD include most of the industrialized market economies of the world; they are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, West Germany, Greece, Iceland, Ireland, Italy, Japan, Luxemburg, Netherlands, New Zealand, Portugal, Norway, Spain, Sweden, Switzerland, Turkey, U.K., and U.S.

traditional fuels are particularly important in the developing countries, which contain the bulk of the world's population. In some regions, these fuels are in critically short supply.

The major characteristics of all of these diverse energy sources are that they are designed to be used in specific applications with rather specific equipment. Only in a few applications, such as specially designed boilers, furnaces, or kilns, can a variety of fuels be used interchangeably. Most energy-using equipment is energy-source specific. Hence energy substitution is usually difficult. Given the relatively long life expectancies of most equipment and appliances (from four years for a truck to up to 50 years for a smelter or industrial furnace) change-overs from one source of energy to another are not easily accomplished. Usually, the equipment has to be replaced first and this may not be economical until it has outlived its usefulness. Furthermore, existing equipment operates at specific energy efficiency rates. These can rarely be changed without replacement of the equipment itself. Both of these factors, the long-life of equipment and its built-in energy efficiency make it difficult to change energy consumption rates in the short-run in response to substantial changes in costs. In the long-run, however, significant substitutions can be accomplished by switching from higher-cost to lower-cost energy sources, or by increasing energy-use efficiencies of equipment through substitutions by more sophisticated designs and/or lower-cost labor or capital.

However, in order to bring such changes about, appropriate energy demand management policies are needed that provide users with the appropriate signals (either through higher prices, persuasion, or direct intervention). This is why demand management is so important for the overall task of energy management.

Chapter 3 begins with a discussion of the functioning of ideal energy markets in an economically efficient manner, and then goes on to identify the real world problems that give rise to market distortions such as monopoly power, externalities, indivisibilities, and so on. Therefore, some government intervention is usually necessary, ranging from mild oversight, guidance, and decentralized incentives in a market economy, to more direct control of practically all aspects of energy sector activities in a centrally planned economy.

The scope of energy planning is defined, and the specific role of demand management is described next in Chapter 3. It is generally accepted that the broad rationale underlying modern energy management and planning is to make the best use of available energy resources for promoting economic development, and improving social welfare, and the quality of life. Therefore, energy planning is an essential part of the overall management of the national economy, and should be carried out in close coordination with the latter. However, in energy management and planning, the principal emphasis is on the comprehensive and disaggregate analysis of the energy sector, with due regard for the

main interactions with the rest of the economy, and among the different owned, energy subsectors themselves. The efficient management of government owned energy related corporations, and where necessary, the provision of correct investment and price signals to the private sector, are an integral part of successfully implementing national energy policies.

In a strictly technical sense, the best strategy might be to seek the least-cost method of meeting future energy requirements. However, energy planning also includes a variety of other and often conflicting objectives, such as reducing dependence on foreign sources, supplying basic energy needs of the poor, reducing the trade and foreign exchange deficits, priority development of special regions or sectors of the economy, raising sufficient revenues to finance energy sector development (at least partially), ensuring continuity of supply, maintaining price stability, preserving the environment, and so on.

In general, energy planning requires analysis at the following three hierarchical levels in relation to fundamental national objectives: (1) links between the energy sector and the rest of the economy, (2) interactions between different subsectors within the energy sector, and (3) activities in each individual energy subsector. The steps involved in the planning procedure usually include energy supply and demand analyses and forecasting, energy balancing, policy formulation, and impact analysis, to meet short-, medium-, and long-range goals. Implementation of the results of this analysis could be considered within the framework of a formal national energy master plan (EMP), or a more decentralized policy package that relies on voluntary responses of private energy producers and consumers to market prices. This will generally require the coordinated use of a number of interrelated policy tools such as: (1) physical controls and legislation, (2) technical methods (including research and development), (3) direct investments or investment inducing policies, (4) education and propaganda, and (5) pricing.

Energy planning may be carried out initially at a relatively simple level, but, as data and analytical capabilities improve, more sophisticated techniques, including computer modeling, may be used. The institutional structure could also be rationalized by setting up a central energy authority or ministry of energy, whose principal focus should be on energy planning and policy-making. Some central guidance and coordination of the many policy tools, energy supplying institutions, and consuming sectors is necessary even in countries in which energy supply activities are dominated by the private sector. The influence of government actions in the various energy subsectors is quite pervasive in all countries. However, regardless of the degree of centralization of planning functions, the execution of policy, and day-to-day operations, would remain the responsibility of government institutions or private firms such as electricity utilities or petroleum corporations that already exist.

Demand management includes that group of elements in a national energy