

Energy Supply-Demand Integrations to the Year 2000

Global and National Studies

Third Technical Report of the Workshop on
Alternative Energy Strategies (WAES)

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Preface

In October 1974, leaders of business, industry, government, and academia from a dozen countries convened the first session of the Workshop on Alternative Energy Strategies (WAES). During its two-and-a-half year lifetime, the Workshop carried forward studies of energy demand and supply, of resource availability, and of the critical factors in alternative energy futures, both nationally and globally. These studies provided the essential ingredients for what we call “energy supply-demand integrations”—the comparing and contrasting of separate energy demands and supplies. This book reports the results of our integration studies. It is the third, and final, volume in a series of WAES published technical reports.¹

The Workshop was an ad hoc international project, involving over seventy-five people from a total of fifteen countries. It set itself the goal of assembling a set of coherent global energy pictures of the future. To this end, it developed methods for estimating energy supply and demand through the year 2000 and for combining, comparing, and contrasting them.

This goal was set against a background which recognized that, according to the best estimates, world crude oil production will peak and begin to decline within the next twenty-five years. The transition from oil to other forms of energy is coming more rapidly than most people realize. WAES evolved out of the common concern of a number of influential people who believed that this transition needed to be widely understood and effectively managed in order to avoid major national and international dislocations.

During our studies and deliberations in the Workshop, it became clear that future energy problems are fundamentally problems of *imbalance*—of mismatches between limited supplies of certain fuels and “preferred” demands for such fuels. Certain fuels are best suited to meet certain types of energy demand and, for economic, thermodynamic, efficiency, or other reasons, not necessarily ideally suited to meet other types of energy demand. The WAES energy balances—or what we call “supply-demand integrations”—show this.

1. The first two technical reports are *Energy Demand Studies: Major Consuming Countries* (MIT Press, 1976) and *Energy Supply to the Year 2000: Global and National Studies* (MIT Press, 1977).

What will be the future fuel preferences throughout the world? Will the preferred fuels be available in quantity? If not, are there shifts that can be made in a nation's, or the world's, fuel-use patterns? Are such shifts sufficient to allow the demands for energy to be met?

This third technical report of the Workshop seeks to treat these issues, country by country and for the world outside Communist areas (WOCA), in a carefully constructed way, for the years 1985 and 2000. It contains details of energy supply and demand balances or projected imbalances for the base year, 1972, and for 1985 and 2000 for thirteen countries, for the aggregated developing countries, and for WOCA. These integrations are done under five different “scenarios” to 1985 and four to 2000, based on a combination of variables representing economic growth, energy price, national energy policy, and principal replacement fuel.

The Workshop's demand estimates for 1985 are contained in the first technical report, the supply estimates to 2000 in the second technical report. Projections of energy demand to 2000 can be found in the national chapters of this third volume.

The WAES final report—*ENERGY: Global Prospects 1985-2000* (McGraw-Hill, 1977)—summarizes the global character of the WAES findings. It draws heavily on the substance of the three-volume technical report series. It identifies the major long-term energy problems that appear as a result of our studies and draws some implications for nations acting together and nations acting alone.

The Workshop on Alternative Energy Strategies was an independent organization, with no official ties to any governments or private firms.² It was organized into three groups:

- The *Participants*, thirty-five senior decision makers from around the world, whose experience in dealing with problems involving the interplay of technology, economics, finance, and government policy made them well-suited to take an active part in the Workshop. Members included officials from organizations that are suppliers and users of fuels or that produce electricity, government officials with energy-related responsibilities, and others whose insights enriched the Workshop. The *Partic-*

2. Further information about the Workshop can be found in “A Global Energy Assessment 1985-2000,” a brochure available from any of the Workshop members.

ipants took part in this study as individuals, not as official representatives of their organization or country. They provided or arranged for financial support for WAES activities in their own country and paid for the expenses involved in attending and sponsoring meetings.

- The *Associates*, chosen by the Participants from their own or cooperating organizations, included scientists, engineers, economists, and managers with expertise in many energy-related fields, who brought a wealth of broad experience to the Workshop. They conducted the technical studies that form the basis for the Workshop's findings and conclusions.

In some countries Workshop members recruited Reference Groups—people from government and industry who served as advisers, provided financial support, and did some of the analytical work.

- The *Secretariat* included the Project Director and a small staff at the Massachusetts Institute of Technology. The Director provided executive leadership, and the Secretariat provided project coordination. Secretariat expenses were supported by foundation grants.

This distinctive character allowed the Workshop to have two important effects. Through its technical analyses it provided the necessary quantitative basis for policy decisions. More directly, involvement in such an in-depth study influenced the members themselves, who will, it is hoped, assist in the process of turning the options identified by the Workshop into realities.

The Workshop objectives were to establish a quantitative basis for analyzing probable future energy developments through the year 2000 and then identifying feasible alternative global and national energy strategies to deal with these developments. The analyses were designed to provide information that would raise the level of public understanding and assist governments and others in making the choices and formulating the strategies necessary to ensure a proper balance of energy supply and demand during the period 1985 to 2000 and beyond.

Few nations, acting alone, have the resources to ensure their own energy supplies. Therefore, it is in the common interest to avoid placing insupportable demands on specific energy sources. For example, it makes no sense for one country to build power stations that will depend on coal from another country if the latter does not develop the needed capacity for coal production, transport,

and export. The international nature of WAES allowed a global approach to such issues.

In looking at the period to the end of the century, it is important to try to determine what can be achieved in the time available. Economic growth and energy "savings" will be the main determinants of energy demand up to 1985, with oil remaining the principal fuel. Beyond 1985, alternative energy sources will be needed on an increasing scale. Because of the long lead times required, however, the size of their contributions will be determined by actions taken now or in the very near future.

A description of the overall methodology developed by the Workshop is given in chapter 1, together with a detailed description of the energy supply-demand integration studies methodology. This novel approach to the global energy setting draws partially on many traditional analytical techniques and tools, which have been modified and adapted by the Workshop Associates with the guidance and assistance of the Participants. The WAES methodology was endorsed and supported by all Workshop members. Each national study is, however, attributable solely to the Workshop members from that country, and although all studies were done in a common and consistent manner, each has its own distinctive aspects.

As with any study of the future, the projections in this volume should be taken with care. The Workshop claims no special ability to see into the future. It does claim, however, to have projected reasonable estimates for energy demand and supply, and their possible global balance or imbalance, in its member countries and in the world outside Communist areas. Such projections are based on explicit assumptions about several alternative states of the world.

There are differences among national approaches. Many of these variations in national style and decision making are revealed by the studies in this book. These differences add richness to the studies and illustrate some of the potentials for change in present-day patterns of energy use. We hope that such potentials will be carefully assessed by the many analysts, scientists, and research groups outside the Workshop who have the ability and time to do so.

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The studies and analyses upon which this report is based result from substantial contributions by many in WAES. The national reports, chapters 7 through 19, represent extensive efforts by all national teams over the course of the Workshop. Each of these chapters is the responsibility of the Associates from the given country.

The chapters in Part II were prepared by various Associates, although they present work which was the product of contributions by all Associates. Edward Griffith developed the Global Energy Data Base of chapter 3, which summarizes the data supplied by national teams for global integrations. Richard Eden and Edmund Crouch prepared chapter 4, the description and results of the WAES unconstrained global integrations. David Sternlight and Edward Griffith prepared chapter 5, the description and results of the WAES constrained global integrations. Andrew Flower contributed importantly in the coordination of the two global integration techniques. Chapter 6, which describes the energy prospects of the developing countries, was prepared by William F. Martin and Frank J. P. Pinto (a consultant to WAES and the World Bank), who gratefully acknowledge the assistance of Nicholas Carter, John Foster, and William Humphrey of the World Bank and Alan Strout of the MIT Energy Laboratory.

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Part I

Introduction and Overview

1.1 THE CONCEPTUAL FRAMEWORK

1.1.1 Introduction

No widely accepted methodology exists for projecting energy supply and energy demand for periods of ten to twenty-five years into the future. Therefore, the first major tasks of the Workshop were to identify and agree on the major determinants of future energy supply and demand, to select a range of likely values for these determinants, and to develop an internally consistent and comprehensible framework for synthesizing the various national and global studies.

The period under study was divided into two time frames: (1) the period from 1972 to 1985, in which the contribution of each energy source is largely determined by existing infrastructure and projects already under development; and (2) the period from 1985 to 2000, when pressures on oil and natural gas supplies will increase, alternative energy supply systems could make major contributions, and energy conservation measures now only beginning could reduce energy demand—provided that these systems are started and developed soon enough and implemented on a sustained basis.

No single forecast can encompass all of the uncertainties of the next twenty-five years. The Workshop therefore identified a range of different but plausible futures; that is, a “scenario” approach was adopted. “Scenario” is the term used to represent a plausible future—for our purposes, with particular reference to energy. Several scenarios were defined and analyzed by the Workshop. For each scenario, values of key variables were specified and the consequent energy picture evaluated. Scenarios are not forecasts; they are chosen to span a wide range of possible futures that lead to different estimates of energy demand and supply.

1.1.2 The Overall Framework¹

The real world² of energy decisions is highly inter-

1. A discussion of the WAES approach in a general, global context can be found in the WAES report, *ENERGY: Global Prospects 1985-2000* (McGraw-Hill, 1977).
2. Members of the Workshop come from energy-consuming nations in the world outside Communist areas. Although the USSR and China are major world energy producers and consumers, their trade in fuels with the countries in the world outside Communist areas (WOCA) has to date been relatively small. In the WAES projections, this situation was assumed to continue through the end of the century.

active and too complex to be simulated precisely. So WAES constructed a model—a simplified conceptual framework—of the real energy world (Figure 1.1). Its essential feature is that it separates those global factors not under control of individual, energy-consuming nations from those factors under national control. The method used in WAES involves seven basic steps, shown in Figure 1.1 from top to bottom.

Step 1 defines in broad terms the sorts of “energy worlds” that might evolve between now and 2000 by making various assumptions about world economic growth and the world price of oil or energy, the key determinants of energy supply and demand outside the control of individual national decision-making processes. The values we selected are not predictions but plausible values that adequately span the WAES assessment of the likely future states of the world—given the assumption that the past trends of world economic growth may be extrapolated into the future.

Step 2 introduces, as a third global scenario variable, a factor that nations can control—the national

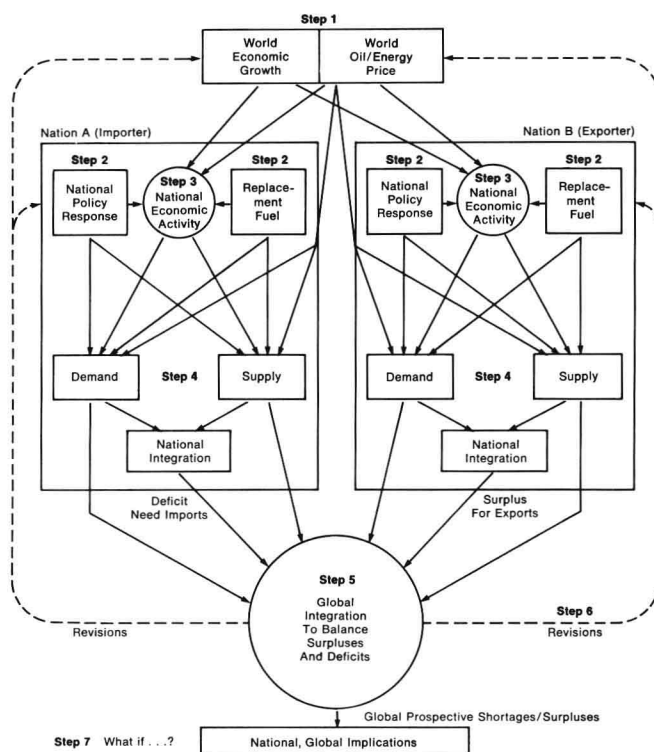


Figure 1.1
The WAES conceptual framework for world energy futures.

public policy response to the emerging energy situation. It is assumed that until 1985 each nation has either a vigorous or a restrained national energy policy response: for example, a vigorous policy might include an active search for new sources of supply or a campaign to promote energy conservation. From 1985 to 2000 energy policies of all nations are assumed to be vigorous. Also during the 1985 to 2000 period, a major energy policy question facing nations could well be framed as: What will be the principal replacement fuel for oil as it declines in availability? This is the fourth global scenario variable for this period: whether coal or nuclear will be the principal replacement fuel. Nations may make different choices, but such choices can be added to obtain global (WOCA) totals.

Step 3 moves from these global scenarios to corresponding regional and national scenarios. Each national team individually translated and applied the global assumptions to its own national economic assumptions, taking account of such factors as trade capability and industrial infrastructure.

Step 4 analyzes in detail national energy supply and demand under world, regional, and national assumptions. Each WAES team calculated independent estimates of desired demand and potential supply. Desired demand is what each nation would like to use (assuming that supplies for each kind of fuel are available) at the given price, economic growth, and policy assumptions. Maximum potential supply is the amount that could be produced within a country given the scenario assumptions. These demand and supply estimates do not take into account the availability or unavailability of fuel imports or markets for potential exports. These demand and supply studies are done independently and are then matched in the national supply-demand integration process.

Many existing national energy forecasts stop at step 4 and simply assume that any gap between demand and domestic fuel production can be filled by imports. *Step 5* goes on to compare the fuel imports and exports of the national supply-demand integrations with global fuel availability by means of an international balancing calculation.

The global integration technique will be described later in this chapter. For now it is only necessary to state that WAES has used two kinds of integration: *unconstrained* and *constrained*.

From the global integrations, an overall energy

balance (or imbalance) is obtained—the total energy supplies and demands, including shortfalls and surpluses, for each major fuel and for each scenario case under both the unconstrained and constrained alternatives. The feasibility, consistency, and likelihood of each scenario can then be evaluated for each country.

Step 6 in the WAES framework allows a major choice. Either the analysis can end here, presenting the results as a final projection indicative of prospective shortages or surpluses of fuels in the future; or, if the projection points to severe prospective energy shortages, or other major problems—in fact, to an impossible or highly undesirable future—assumptions can be altered or new scenarios can be calculated. This revision process is shown by the dashed lines in Figure 1.1. Such revisions might be motivated by, for example, balance-of-payments problems in oil-importing countries—causing increased development of domestic resources and greater fuel switching. WAES has not studied balance-of-payments questions in depth.

Step 7 lies outside the main conceptual framework. Here WAES could ask, in effect, what would happen if the main assumptions proved incorrect? What if Saudi Arabian oil production were to be held near present levels? What if there were a moratorium on nuclear power? What if solar energy rapidly became cheaper than expected? And so on. Such questions are partly explorations of the need for strategies, but they also test the impact of major uncertainties on WAES scenarios.

The next two subsections define more explicitly the scenario variables used by WAES and their combinations into the scenario cases selected for analysis.

1.1.3 The Scenario Variables

For both demand and supply projections, WAES defined the global variables given below.

World Energy Price

To 1985 energy price assumptions were based on the price of oil (in constant 1975 U.S. dollars) because oil will continue to be the dominant as well as the balancing fuel and other internationally traded fuels will therefore be priced in relation to oil. Three alternative price assumptions were made.

- Constant real price: No change from the January