OCCASIONAL PAPERS

Pacific Energy Outlook: Strategies and Policy Imperatives to 2010

Edited by
Fereidun Fesharaki
Allen L. Clark
Duangjai Intarapravich

EAST-WEST CENTER
OCCASIONAL PAPERS
Energy and Minerals Series
No. 1, March 1995

EAST-WEST CENTER

The U.S. Congress established the East-West Center in 1960 to foster mutual understanding and cooperation among the governments and peoples of the Asia-Pacific region, including the United States. Principal funding for the Center comes from the U.S. government, with additional support provided by private agencies, individuals, and corporations, and more than 20 Asian and Pacific governments.

The Center promotes responsible development, long-term stability, and human dignity for all people in the region and helps prepare the United States for constructive involvement in Asia and the Pacific.

The Program on Resources: Energy and Minerals (PREM) was established in 1991 as a unit of the East-West Center. PREM conducts research in the two broad program areas of energy and minerals. The research focuses on commercial energy resources (oil, natural gas, coal, electric power generation) and metallic and nonmetallic minerals in the Asia-Pacific region and the Western Hemisphere.

PREM's research addresses critical issues such as supply security, strategies for efficient development and utilization of domestic energy and minerals, and the mitigation at local and global levels of negative social and environmental impacts. The main goal of PREM is to assist national planners in government and the private sector in the formulation of effective programs that coordinate national policies, including economic development and growth, security of energy and mineral supplies, and maintenance of the environment.

East-West Center Occasional Papers: Energy and Minerals Series facilitates early dissemination of the Center's research findings and policy-relevant reports. All manuscripts are peer-reviewed.

East-West Center
1777 East-West Road
Honolulu, Hawaii 96848, USA
Telephone: (808) 944-7145
Facsimile: (808) 944-7376

Pacific Energy Outlook: Strategies and Policy Imperatives to 2010

Edited by

Fereidun Fesharaki

Allen L. Clark

Duangjai Intarapravich

EAST-WEST CENTER
OCCASIONAL PAPERS
Energy and Minerals Series
No. 1, March 1995

About the Editors

Fereidun Fesharaki is the director of the Program on Resources: Energy and Minerals, East-West Center. Born in Iran, he received his Ph.D. in economics from the University of Surrey in England and was a visiting fellow of the Center for Middle Eastern Studies, Harvard University. In the late 1970s he attended the OPEC Ministerial Conferences in his capacity as energy adviser to the prime minister of Iran. He was the 1993 president of the International Association for Energy Economics, serves on the editorial boards of several international energy journals, is a member of the Advisory Boards of the Mitsubishi Oil Company (Japan) and the Far East Oil Price Index (Singapore), and has been a member of the Council on Foreign Relations since 1989.

Allen L. Clark is a senior fellow of the Program on Resources: Energy and Minerals, East-West Center. He received his Ph.D. from the University of Idaho and completed postdoctoral studies in economics at Stanford University. He is the founder of the Office of Resource Analysis within the U.S. Geological Survey and the founder and a former director general of the International Institute for Resource Development in Vienna, Austria. He currently serves on the editorial boards of several technical journals and is a fellow of the New York Academy of Sciences.

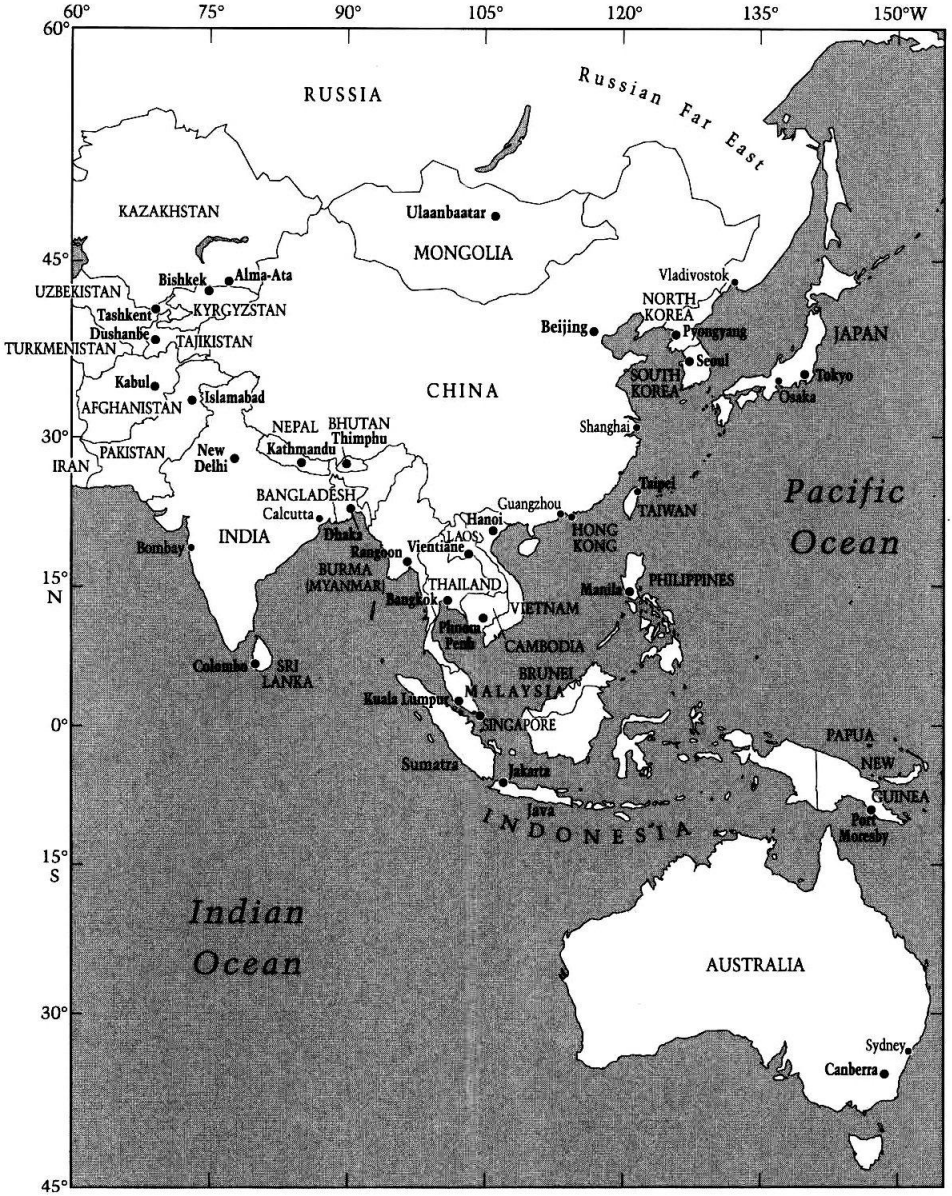
Duangjai Intarapravich is the acting director of the Energy and Environment Program at the Thailand Environment Institute (TEI). She was a visiting fellow at the East-West Center from January 1993 to October 1994. Prior to coming to the Center, she was a research fellow of the Thailand Development Research Institute. She received her Ph.D. in Mineral and Energy Resources Economics from the University of West Virginia. She can be reached at TEI, 210 Sukhumvit 64, Bangchak Refinery Building 4, Prakhanong, Bangkok 10260, Thailand.

LIBRARY OF CONGRESS CATALOGING-IN-PUBLICATION DATA

Pacific energy outlook : strategies and policy imperatives to 2010 / edited by Fereidun Fesharaki, Allen L. Clark, Duangjai Intarapravich.
p. cm. — (East-West Center occasional papers. Energy and minerals series ; no. 1)
Prepared by staff of the Program on Resources: Energy and Minerals (PREM).
ISBN 0-86638-173-2 (pbk.)
1. Energy policy—Pacific Area. 2. Energy industries—Pacific Area—Forecasting. 3. Energy policy—Asia. 4. Energy industries—Asia—Forecasting. 5. Energy policy—Russia (Federation)—Russian Far East. 6. Energy industries—Russia (Federation)—Russian Far East—Forecasting. I. Fesharaki, Fereidun. II. Clark, Allen L., 1938- . III. Dūangčhai Inthraprawit. IV. Prepared by staff of the Program on Resources: Energy and Minerals (East-West Center). V. Series: East-West Center occasional papers. Energy and minerals series ; no. 1.
HD9502.P162P35 1995
333.79'09182'301—dc20 95-10496
CIP

Figures

Tables


60°
75°
90°
105°
120°
135°
150°W
60°
45°
30°
15° N
0°
15° S
30°
45°
RUSSIA
Russian Far East
KAZAKHSTAN
Ulaanbaatar
MONGOLIA
Vladivostok
NORTH KOREA
Pyongyang
Beijing
JAPAN
Seoul
SOUTH KOREA
Tokyo
Osaka
Bishkek
Alma-Ata
UZBEKISTAN
KYRGYZSTAN
Tashkent
Dushanbe
TAJIKISTAN
TURKMENISTAN
Kabul
Islamabad
AFGHANISTAN
CHINA
Shanghai
NEPAL
BHUTAN
Thimphu
Kathmandu
PAKISTAN
New Delhi
IRAN
Taipei
TAIWAN
Guangzhou
BANGLADESH
Calcutta
Dhaka
Hanoi
LAOS
HONG KONG
Pacific Ocean
INDIA
Bombay
Rangoon
Vientiane
BURMA (MYANMAR)
THAILAND
Manila
PHILIPPINES
Bangkok
VIETNAM
Phnom Penh
CAMBODIA
Colombo
SRI LANKA
BRUNEI
Kuala Lumpur
MALAYSIA
SINGAPORE
PAPUA NEW GUINEA
Sumatra
Jakarta
Java
INDONESIA
Port Moresby
Indian Ocean
AUSTRALIA
Sydney
Canberra

The Asia-Pacific region has emerged as the engine of growth of world energy markets. The pent-up demand for energy, coupled with fast economic growth and liberalization policies, has unleashed unprecedented demand growth in the region, which is shaping the future of the global energy markets. At the same time, energy supplies are lagging behind the explosive demand growth rates, forcing the region to become the largest energy importing area in the world.

In Asia, there are no coherent publicly available data or coordinated regional statistics. While the Asian Development Bank, the United Nations, and the International Energy Agency have made great progress in collecting data over the past few years, up-to-date data are not available. The data are sometimes inconsistent and not always in a form that can be used to provide a regional picture. This reflects the differences in methodologies and definitions used in the Asia-Pacific region, as well as a general reluctance by the countries of the region to share their data. A similar problem is encountered when studying their energy policies. Nothing that the analyst learns about one Asian country's energy situation, policies, and trends is transferable to the study of another country. For example, understanding Japan's energy situation does not tell the analyst anything about South Korea; a knowledge of Indonesia's energy situation does not provide insights about Thailand; and the energy situations in China and India have little in common. In short, understanding the regional market is possible only by carrying out a country-by-country analysis, not only of energy data and GNP growth rates but also of detailed factors that drive each country's energy policy. This requires a major commitment of time, a focus exclusively on the region, and an intricate network of key industry and government officials to undertake a bean-counting approach on a country-by-country basis.

The Program on Resources: Energy and Minerals (PREM) of the East-West Center has maintained a leadership role in the analysis of the Asia-Pacific energy markets for more than a decade. The research staff have an intense knowledge of every country and the key energy sectors, enabling them to develop an integrated picture of the Asia-Pacific region and a vision of future developments. The *Pacific Energy Outlook* provides a concise overview of our analysis of and forecasts for the energy sector in the Asia-Pacific region to the year 2010.

I would like to thank Drs. Duangjai Intarapravich and Allen Clark who coedited the volume and our staff members who contributed to this integrated energy picture of the region. I am also heavily indebted to more than two dozen organizations in industry and government in the Asia-Pacific region, who assist us on a regular basis with data, analysis, and explanations of the intricate complexities of the national energy policy in each country in the region. Without their goodwill and generosity, this integrated analysis would not have been possible.

Fereidun Fesharaki
Director
Program on Resources: Energy and Minerals

Cary Bloyd
Chapter 5

James P. Dorian
Chapter 2, Domestic Energy Prices (with Heather Keevill)

Fereidun Fesharaki
Chapter 1

Duangjai Intarapravich
Chapter 2, Electric Power Generation Assumptions (with Charles J. Johnson, Binsheng Li, and Kang Wu); Chapter 3, Electricity

Charles J. Johnson
Chapter 2, World Energy Prices (with Widhyawan Prawiraatmadja and Frank C. Tang); Chapter 2, Electric Power Generation Assumptions (with Duangjai Intarapravich, Binsheng Li, and Kang Wu); Chapter 3, Coal (with Binsheng Li and Scott Long)

Heather Keevill
Chapter 2, Domestic Energy Prices (with James P. Dorian)

Eugene Khartukov
Chapter 4, Newly Independent States and Russian Far East

Binsheng Li
Chapter 2, Electric Power Generation Assumptions (with Duangjai Intarapravich, Charles J. Johnson, and Kang Wu); Chapter 3, Coal (with Charles J. Johnson and Scott Long)

Scott Long
Chapter 3, Coal (with Charles J. Johnson and Binsheng Li)

Shiva Pezeshki
Chapter 3, Natural Gas

Widhyawan Prawiraatmadja

Chapter 2, World Energy Prices (with Charles J. Johnson and Frank C. Tang); Chapter 3, Oil (with Frank C. Tang and Kang Wu)

Frank C. Tang

Chapter 2, Macroeconomic Outlook; Chapter 2, World Energy Prices (with Widhyawan Prawiraatmadja and Charles J. Johnson); Chapter 3, Oil (with Widhyawan Prawiraatmadja and Kang Wu); Chapter 4, China

Kang Wu

Chapter 2, Electric Power Generation Assumptions (with Duangjai Intarapravich, Charles J. Johnson, and Binsheng Li); Chapter 3, Oil (with Widhyawan Prawiraatmadja and Frank C. Tang)

Introduction

The center of gravity of the world's energy market is shifting to the Asia-Pacific region and will continue to do so until 2010 and beyond. This shift is due to the region's rapid economic growth and increasing population (which is currently about 60% of total world population). The region's oil demand has already surpassed Western Europe's and will soon overtake North America's. Also, the region is involved in more than three-fourths of the world's trade in liquefied natural gas (LNG). Given these trends, a thorough understanding of the energy outlook of the Asia-Pacific region is of utmost importance to industry and governments—nationally, regionally, and internationally. To meet this need, the East-West Center's Program on Resources: Energy and Minerals has undertaken an analysis of the energy sector from 1993 to the year 2010, using high, low, and base case scenarios for the following economic groups within the region:

- OECD Pacific (Australia, Japan, New Zealand)
- Newly industrialized economies (NIEs) (Hong Kong, Singapore, South Korea, Taiwan)
- Southeast Asia (Indonesia, Malaysia, the Philippines, Thailand, Vietnam)
- South Asia (Bangladesh, India, Pakistan)
- China
- Other Asia-Pacific economies.

The aggregate data for the Asia-Pacific region, presented in this chapter and in chapter 3, are based on these six categories. The category of "other" economies comprises the Pacific island nations and all the countries of Asia not listed above, with the exceptions of the former Soviet Union and the Middle East (including Iran). Summary data on the former

Soviet Union are provided in a separate section of this chapter and are discussed in greater detail in chapter 4.

KEY ASSUMPTIONS

Key crude oil prices per barrel of Arab Light type crudes are assumed to be real US$20 in the year 2000 and US$27 in 2010. Natural gas prices are expected to remain dependent at least partially on oil prices to 2010. Therefore, LNG prices will increase with crude oil prices. Constant prices of US$35–40 per tonne of thermal coal are projected for the same period.

Our evaluation of regional energy demand in the context of regional and national energy prices recognizes that the nations of the Asia-Pacific region have historically adopted regulated domestic pricing. Although there is currently a strong trend away from such practices, their persistence will continue to shape the region's energy market to some extent.

The growth of gross domestic product (GDP) is projected to be in the range of 1.2–2.4 percent in the OECD Pacific countries; 5.0–7.5 percent in the NIEs; 6.3–8.0 percent in Southeast Asia; 4.5–6.0 percent in South Asia; 6.3–8.5 percent in China; and 6.1–6.7 percent in the other countries of the region.

The projection of total power generation is based on the forecast demand for electricity which, in turn, is closely tied to GDP growth rates. Our analysis covers only generation by public utilities and does not include private self-generation. Total installed capacity has been estimated from projected peak demand and planned reserve margin. We assume that most of the capacity added in the region during the outlook period will be thermal power plants, with coal the major fuel.

Generation from nonfossil sources will increase in some countries, including nuclear in Japan, China, India, and South Korea and hydro in South Asia. Geothermal generation will be further developed, notably in Indonesia and the Philip-

pines, but will continue to contribute only a small proportion of total generation.

The main conclusions of this study, using the base case scenarios, are outlined in the following section.

BASIC CONCLUSIONS OF THE STUDY

Oil product demand in the Asia-Pacific region (excluding direct burning of crude in China and Japan) is expected to increase from 14.9 million barrels per day (mmb/d) in 1993 to 19.8 mmb/d in 2000, growing at a rate of 4.1 percent per year on average. From 2000 to 2010 it will grow by 3.0 percent per year on average and reach 26.6 mmb/d. The demand pattern will continue to skew toward lighter oil products, because of rapid expansion of the region's motor transportation sector. At the same time, the demand for fuel oil will be dampened because of the increasing importance and availability of substitutes, especially coal and natural gas as fuels for power generation. Diesel's share of total product demand is expected to increase from 30.3 percent in 1993 to 31.9 percent in 2000 and 33.6 percent in 2010. Gasoline's share will increase from 17.5 percent in 1993 to 18.8 percent in 2000 and 21.1 percent in 2010. On average during the period 1993–2010, however, the annual growth rate of gasoline (4.6%) will exceed that of diesel (4.1%). Fuel oil demand will increase at an annual average rate of only 1.0 percent during this period. Fuel oil's share of total product demand is therefore expected to decline from 20.7 percent in 1993 to 17.1 percent in 2000 and 13.9 percent in 2010.

The region's crude oil production, after reaching 6.9 mmb/d in the mid-1990s, will remain virtually unchanged for the rest of the decade. By 2010, however, it will decline slightly (to 6.5 mmb/d). This projection reflects a short-term increase, followed by a gradual decline, in Indonesian and Malaysian production; a strong and steady increase in Vietnamese, Chinese, and Burmese production; and a much slower decline in Australian output than previously expected.

Asia-Pacific crude production is unable to satisfy exist-

ing regional demand, and the gap between supply and demand will widen rapidly. The result will be a major increase in import dependence. Oil imports from outside the region, primarily from the Middle East, will account for two-thirds of the region's consumption by 2000 and three-fourths by 2010. The region's net oil imports from outside the region consisted of 6.9 mmb/d of crude and 1.7 mmb/d of products. Net imports are projected at 10.5 mmb/d of crude and 2.8 mmb/d of products in 2000 and 16.6 mmb/d of crude and 3.5 mmb/d of products in 2010.

Natural gas has become the fuel of choice in the Asia-Pacific region—in particular among the power generation utilities, which place a premium on gas because of security of supply, minimal price volatility, and environment-friendly qualities. It is expected that gas use will expand, as additional discoveries are made, as the gas distribution system develops, and as a "gas utilization culture" emerges in the region. In almost any scenario, therefore, natural gas demand will continue to increase significantly. The base case growth rate (about 6% per year during 1994–2010) would raise total natural gas demand in the region to 16.2 trillion cubic feet per year at the end of the next decade.

Japan will continue to be the most important LNG consumer in the world. LNG demand in Japan is expected to increase from 39.3 million tonnes (mmt) in 1993 to 54 mmt in 2000, and it could be as high as 70 mmt in 2010. In South Korea, LNG demand was 4.5 mmt in 1993 and will probably reach 10 mmt in 2000. Taiwan's LNG demand is expected to rise from 1.8 mmt in 1993 to about 7 mmt in 2000, as gas-based power generation capacity jumps from 1,027 MW in 1993 to 6,045 MW in 2000. By the year 2010, the combined South Korean and Taiwanese demand is expected to reach 30 mmt. New LNG consumers (China, India, and Thailand) could push the region's total LNG demand in 2010 above 100 mmt, which will be more than double the present level.

The share of coal in total primary energy consumption is higher in the Asia-Pacific region than in any other region in the world. About 46 percent of the region's commercial

energy requirement is provided by coal, compared with 21 percent for the remainder of the world. The dominant factor in the high percentage of coal use in the region is China, which is the world's leading producer and consumer of coal.

Among the significant coal producers in the Asia-Pacific region, output is projected to grow 3.7 percent per year on average, from 1.67 billion tonnes in 1993 to 2.22 billion tonnes in 2000 and 3.07 billion tonnes in 2010. China, India, and Australia are expected to account for 94 percent of the region's growth in coal production. Total consumption (projected to increase by 3.7 percent per year) will rise from 1.69 billion tonnes in 1993 to 3.1 billion tonnes in 2010. Two countries—China and India—will account for more than 80 percent of the region's coal consumption during this period.

Coal is by-far the region's most abundant fossil fuel resource, and it will continue to be the dominant primary fuel consumed during the outlook period. Coal is a major contributor to air pollution, however, and it is facing challenges from cleaner alternatives: natural gas, nuclear power, and hydropower. A critical factor in any projection of the region's coal use during the outlook period is the ability of coal to meet increasingly tighter environmental standards and still remain competitive with alternative energy options. Clean coal technologies add about $0.01 per kilowatt hour (kWh) to the price of electricity, which typically sells for $0.05–$0.08 per kWh in Asia. Notable exceptions are China and India, where average prices are about $0.03 per kWh, and Japan, where prices exceed $0.11 per kWh plus a very heavy tax. High-efficiency clean coal technologies can add 15–30 percent to the capital cost of power plants in the Asia-Pacific region, but efforts are being made to develop lower cost (albeit less efficient) technologies that could have wider applications in lower income economies.

The average annual growth rates of electricity generation in the region are forecast at 6.5 percent during 1993–2000 and 5.3 percent during 2000–2010. Asia-Pacific power growth will therefore be faster than the projected world economic growth rates of 2.4 percent and 3.1 percent during the

respective periods. The high power growth rates will be in the Southeast Asian and South Asian economies and in China, where electrification rates are still low but are expected to increase in the next decade. High economic growth rates in the Southeast Asian countries during the outlook period will accelerate growth in electricity demand. In contrast, growth rates of electricity generation in the more mature economies, such as the OECD Pacific and the NIEs, will be relatively low since most economic sectors already have access to electric power.

Total power generation in the Asia-Pacific region is projected at 4,135.6 terawatt hours (TWh) in 2000 and 6,958 TWh in 2010, compared with 2,668.6 TWh in 1993. The predominant fuel source in 2010 will be coal, followed by hydropower, natural gas, nuclear power, and oil. The remaining generation will be provided by geothermal and other renewable sources of energy.

The coal share of total generation in the region is expected to increase from 45.0 percent in 1993 to 49.9 percent in 2010. During the same period, increases are likewise expected in the shares of nuclear generation (from 12.0% to 13.8%), gas fired generation (from 11.7% to 13.8%), and hydro generation (from 15.5% to 16.8%). In contrast, the share of oil will fall from 15.4 percent in 1993 to 8.3 percent in 2000 and only 4.8 percent in 2010.

Electricity generation from fossil fuel is projected at 3,000.5 TWh in 2000 and 4,766.5 TWh in 2010. Coal will provide 2,135.6 TWh (71.2% of the total in 2000), gas will provide 520 TWh (17.3%), and oil will provide 344.9 TWh (11.5%). The shares of coal and gas will increase, respectively, to 72.8 percent (3,469.9 TWh) and 20.2 percent (962.8 TWh) in 2010, whereas the share of oil will decline to 7.0 percent (333.8 TWh). Hydro generation is expected to increase from 413.5 TWh in 1993 to 605.6 TWh in 2000 and 1,166.0 TWh in 2010. The growth rate of hydro generation is projected at 5.6 percent per year during 1993–2000 and 6.8 percent per year during 2000–2010.

Between 1993 and 2010, nuclear generation in the re-

gion is projected to increase at an average annual rate of 6.6 percent, from 321.2 TWh to 952.6 TWh. The greater part of 2010 nuclear generation will be in Japan (478 TWh), followed by South Korea (173.3 TWh), China (122.6 TWh), India (94.8 TWh), Taiwan (63.9 TWh), and Pakistan (20.0 TWh). Total geothermal generation in 2010 is projected at 66.8 TWh: 56 percent (36.8 TWh) in the Philippines, 22 percent (15 TWh) in Japan, 18 percent (12.3 TWh) in Indonesia, and 4 percent (2.8 TWh) in New Zealand. Total 2010 geothermal capacity is projected at 10.2 gigawatts (GW).

The development of renewable resources for power generation is actively pursued on a large scale in only two nations in the region. India provides financial incentives to encourage private investors to develop renewable energy. In 1993, about 167 gigawatt hours (GWh) of electricity was generated by Indian power plants that make use of renewable energy such as wind, biomass cogeneration, solar energy, and biotechnology. India's generation from renewable resources is expected to increase to 566 GWh in 2000 and 1,113 GWh in 2010. Japan, likewise, promotes the development of renewable resources such as waste fired, photovoltaic, and wind powered generation. Japan's targets for these renewable resources are to have 520 MW of installed capacity in 2000 and 1,800 MW in 2010 and to generate a total of 1,000 GWh from these plants in 2000 and 5,000 GWh in 2010. About 500 MW of Japan's installed capacity in 2000 and 1,600 MW in 2010 will be waste fired plants; photovoltaic and wind powered plants will account for 10 MW each in 2000 and 100 MW each in 2010.

In the base case scenario, China's annual GDP growth rate is assumed to be 8.5 percent during 1993–2000 and 6.3 percent during 2000–2010. The growth rate of primary energy consumption in China is projected to be higher during 1993–2000 (4.4%) than during 2000–2010 (3.3%), because of stronger growth in economic activity, increasing urbanization, and expanding road transportation in the 1990s.

Coal will continue to dominate China's energy consumption, although its share of primary energy consump-

tion will decrease from 76.7 percent in 1993 to 72.8 percent in 2000 and 63 percent in 2010. In the power sector, coal consumption is expected to increase by an average of 6.1 percent per year to 2010. The power sector's share of total coal consumption in China is expected to increase from 28.8 percent in 1993 to 51.5 percent in 2010.

China's oil demand is projected to increase by an average of 5.1 percent per year during 1993–2010, and the oil share of final energy demand will increase from 22.5 percent in 1993 to about 30 percent in 2010. China's oil demand will continue to shift to light oil products because of rapid expansion of the transportation sector, which is expected to grow at an average annual rate of about 10 percent during the outlook period. Net oil imports are projected to increase from less than 5 percent of total oil consumption during the two-year period 1993–94 to 21 percent in 2000 and 47 percent in 2010.

Electricity demand in China is projected to grow at average annual rates of 8.7 percent during 1993–2000 and 5.9 percent during 2000–2010. A substantial expansion of nuclear and hydro capacity is expected after the turn of the century, and the shares of nuclear and hydro generation are projected, respectively, at 4.7 percent and 19.5 percent in 2010.

Demand for natural gas will be dampened by China's infrastructure constraints. Although gas consumption is expected to grow faster in the future than it has in the past, its share in primary energy consumption will still be very low. Electricity generated from natural gas will increase substantially and is expected to provide 5.5 percent of China's total generation in 2010.

FORMER SOVIET UNION

The newly independent states (NIS, the countries of the former Soviet Union) will play an important role in shaping the future global energy balance and, in particular, the balance in the Asia-Pacific region. It is difficult, however, to predict the potential energy interflows between the NIS and the rest of the world, because of the economic and political

uncertainties facing the NIS. But such interflows are a key assumption of any related projections, either regional or global. Our base case scenario assumes that the NIS will be a net exporter of oil, gas, and coal and will have an aggregate exportable surplus of 5.7 million barrels of oil equivalent per day (mmboe/d) in 2000 and 7.3 mmboe/d in 2010. At the beginning of the 1990s, the Soviet Union ceased to be a net exporter of electricity, and in 1993 NIS gross imports of electricity exceeded gross exports by about 20 TWh. In the period up to 2010, electricity consumption in the NIS will probably be balanced by domestic and intrabloc supplies, and therefore no net exports of electricity will be available.

The Russian Far East (RFE) is emerging as a new source of energy supplies for the rapidly growing Asia-Pacific energy market. Under the most probable circumstances (our base case), the current heavy dependence of the RFE on outside supplies of crude oil (which provided 79 percent of total 1993 consumption) is likely to decrease to 37 percent in 2010 and 11 percent in 2010. Net RFE imports of crude oil are therefore expected to fall from 123.2 thousand barrels per day (b/d) in 1993 to less than 80 thousand b/d in 2000 and then shrink to only 30 thousand b/d in 2010. The RFE's projected deficit in main oil products (excluding lube oils, bitumen, and LPG) will decrease from 219.4 thousand b/d in 1993 to 198 thousand b/d in 2000 and 158 thousand b/d in 2010. Exportable coal surpluses that are sustainable may appear only after the year 2005 and are likely to be only 10 million tonnes per year in 2010. In contrast, the RFE will have exportable surpluses of natural gas that are both sizable and sustainable: 950 million standard cubic feet per day (scf/d) by 2000 and as much as 1,470 million scf/d by 2010.

THE ENERGY TRADE-OFF

There is significant room for change in the projected energy mix of the Asia-Pacific region. The availability of two key energy sources—nuclear power and natural gas—may prove to be less than the levels of supply currently projected by the governments of the region.

Nuclear power's contribution to electricity generation at the end of the outlook period may be highly exaggerated in official projections. The Japanese government, for example, is forecasting about 70 GW of nuclear capacity in 2010, but insiders believe that the capacity will not exceed 55–60 GW. Similarly, the official projections of installed nuclear capacity in Taiwan and China are higher than the levels that might realistically be achieved. It seems very likely, therefore, that nuclear power generation will fall short—far short—of current projections. In that event, what is the alternative: oil, coal, or gas?

The demand forecasts for natural gas may likewise be excessively optimistic, particularly in the case of LNG. It must be emphasized that all supply and demand projections for LNG are expected, not real. For instance, the Taiwan utility's enthusiasm for LNG is far less today than it used to be. LNG forecasts represent the wish list of governments and industry, but the demand will be dependent on both the actual emergence of buyers and the availability of supplies. Lower-than-expected demand for LNG, together with the current lack of agreement about pricing LNG, may therefore result in a much lower level of LNG consumption than governments are forecasting. If that is the case, where will the energy demand turn: to oil or coal?

In our judgment, both oil and coal will be beneficiaries of lower-than-expected nuclear power and gas supplies in the region. Indeed, the demand for oil and coal could be substantially higher than our current projections, if current plans for nuclear and LNG supplies do not materialize. There is only a minor downside—but a large upside potential—for oil and coal demand in the region to 2010. Many of the region's governments, including Japan, will have no options but to add more oil fired capacity. This means that plans to stabilize or reduce CO_2 emissions will be almost impossible to achieve within this period. Virtually all promises regarding CO_2 that have been made or will be made by governments for the outlook period will not be kept.

IMPORT DEPENDENCE ON THE MIDDLE EAST: DANGER OR OPPORTUNITY?

There can be little doubt that dependence on oil and gas imports from the Middle East will rise in the Asia-Pacific region. This is an unavoidable fact. Does this higher level of dependence represent a serious danger? Does higher vulnerability to Middle East political interruptions represent the Achilles heel of the Asian economic boom? Or does it represent opportunities for the region? The answer is: both. Asia-Pacific countries will have to build special economic and political relationships with the Middle East. There is also no doubt that Asia-Pacific countries will become increasingly concerned with international political issues related to the Middle East. They will seek to build strong ties that bind them economically to the key oil-producing countries in the region.

This trend is not necessarily dangerous, since the Asia-Pacific countries also represent the most important buyers of Middle East oil and gas. The power to buy is just as strong as the power to sell. The Middle East nations will recognize the value of large new customers with huge appetites, advanced technologies, quality consumer goods, and no history of colonial entanglements with the Middle East. For the United States and Europe, however, this redirection of focus and emphasis may prove troublesome, both politically and economically.

Economic Assumptions

It is an extremely difficult task to project Asia-Pacific energy trends to 2010 with any degree of certainty, partly because the region is a complex mix of developed, developing, and newly industrialized economies and has the world's fastest economic growth. In addition, because of the region's large and ever increasing dependence on imported crude oil, numerous external factors must be integrated into the analysis, including world oil prices and supply in particular. Similarly, the issue of coal and gas substitution is a vital but uncertain factor, because of the great difficulties involved in projecting energy developments in China and the countries of the former Soviet Union or the impact of such developments on the region. The countries of the former Soviet Union are not included in the regional data presented in this chapter and are discussed separately in chapter 4.

INTRODUCTION

The projections made in this study are based on the underlying assumptions that the economies of the region will continue to expand, albeit at rates that will decline over time, and that no major disruption will occur in the economic development of China and the newly independent states. Similarly, and most importantly, it is assumed that no major disruptions will occur in the global supply of crude oil. These assumptions will, almost certainly, have to be modified between now and 2010. Government policies are likewise expected to change during this period, in particular with respect to energy pricing, which will alter both our price and our demand-supply assumptions.

This chapter outlines the base assumptions used in this report to develop medium to long term forecasts of energy

supply, demand, and development in the Asia-Pacific region. Energy prices and electricity demand are important determinants of the rate and scope of energy development. This study therefore places emphasis on the rapidly growing demand for electric power generation and on expected prices of crude oil and other energy products, in addition to macroeconomic indicators such as population and economic growth.

MACROECONOMIC OUTLOOK

During the past thirty years, most Asia-Pacific countries have enjoyed spectacular economic growth. Economic success not only has increased the region's share of the global economy, but also has exerted significant impacts on world energy markets, since the region is a net energy importer. In terms of economic performance, it will continue to be the most dynamic region in the world. Growth rates underlying our energy forecast are presented in Table 2.1, which outlines historical and projected GDP and population growth in the region's major economies. Although economic growth has

Table 2.1 Economic and population growth, 1980–93, with projections to 2010

	GDP growth rate (%)				Population growth rate (%)			
Economy	1980–1990	1990–1993	1993–2000	2000–2010	1980–1990	1990–1993	1993–2000	2000–2010
Australia	3.4	2.3	2.0	1.6	1.54	1.51	1.50	1.40
Bangladesh	4.3	4.0	4.5	4.5	2.54	2.45	2.43	2.29
China	9.5	11.4	8.5	6.3	1.47	1.47	1.29	0.85
Hong Kong	7.1	5.0	6.0	5.0	1.21	0.87	0.77	0.55
India	5.3	3.0	5.0	6.0	2.06	1.96	1.90	1.66
Indonesia	5.5	6.6	6.3	6.0	1.99	1.93	1.79	1.43
Japan	4.1	2.7	2.4	1.8	0.56	0.46	0.51	0.26
Malaysia	5.2	8.2	7.5	7.0	2.62	2.43	2.16	1.75
New Zealand	1.9	1.1	1.2	1.2	0.86	1.01	1.01	0.79
Pakistan	6.3	5.3	5.5	6.0	3.26	2.70	2.80	2.48
Philippines	0.9	0.4	7.5	8.0	2.48	2.13	1.98	1.71
Singapore	6.4	7.5	7.5	6.0	1.15	1.11	0.97	0.66
South Korea	9.7	6.0	6.0	5.0	1.29	0.86	0.83	0.53
Taiwan	9.0	6.7	7.0	5.0	1.51	1.06	0.95	0.65
Thailand	7.6	7.8	6.8	6.2	1.57	1.35	1.18	0.99
Vietnam	5.2	7.4	9.0	8.0	2.17	2.16	2.05	1.80
Others	6.3	6.1	6.7	6.1	1.95	1.73	1.62	1.33

varied considerably from country to country, it is expected to be more uniform across countries during the outlook period. In the following section, we examine macroeconomic trends by dividing the region into the following groups: OECD Pacific, newly industrialized economies, Southeast Asia, South Asia, and other economies. China and the newly independent states are discussed separately in chapter 4.

OECD PACIFIC

The OECD countries of the region are Japan, Australia, and New Zealand. Their economies have been maturing, and their GDP growth rates during the outlook period will be considerably lower than those of the past.

NEWLY INDUSTRIALIZED ECONOMIES (NIES)

The Asia-Pacific NIEs are Hong Kong, Singapore, South Korea, and Taiwan. The NIEs have been able to sustain strong economic growth, although the growth rates in recent years have been lower than those achieved on average during the past two decades. The NIEs are in the process of a difficult transition from labor-intensive manufacturing to capital-intensive industries and services. In the long term, these economies will require a concerted effort to improve productivity through technological innovations and improvements in labor skill levels through human resource development. The NIEs' GDP growth will remain strong for the rest of this decade, but will become slower between 2000 and 2010 as their economies mature.

SOUTHEAST ASIA

There are five major economies in Southeast Asia: Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. These economies are more integrated than those of other Asia-Pacific countries, and they have achieved remarkable growth, except for the Philippines. Sound macroeconomic policies

and growth led by manufactured exports ensure that the rapid growth of the Indonesian, Malaysian, and Thai economies will continue well into the first decade of the next century. Vietnam, as it implements economic reforms, is expected to have the highest economic growth rate in this group of countries during the outlook period. The economic growth rate in the Philippines is expected to increase, as the country's investment environment improves.

SOUTH ASIA

GDP projections are provided for the three largest South Asian economies: Bangladesh, India, and Pakistan. India and Pakistan will maintain moderate economic growth during the next three or four years. With the success of their ongoing economic reforms and the improvement of their infrastructure, they are expected to achieve higher growth rates during the rest of the outlook period. Bangladesh, with its limited natural resources, high population density, and vulnerability to natural disasters, can maintain no more than a moderate economic growth rate.

OTHER ASIA-PACIFIC COUNTRIES

Although most of the other Asia-Pacific economies are relatively small, their economic growth is not necessarily slow. Taking into account the strong influence of their neighbors in the region, whose economies are growing rapidly, we assume that the other Asia-Pacific countries as a group will achieve a growth rate equivalent to the unweighted average rate of all the region's economies.

ENERGY PRICE ASSUMPTIONS

Economics dictates that price has an impact on demand. In the energy sector, it is widely believed that the price of oil (the dominant energy source) determines the economics of other energy resources. (See, however, the discussion on coal

in the section below on world energy prices.) The consumer's willingness to pay for other energy resources depends more on the prices of these resources relative to oil than on the absolute price of the energy purchased. Factors that play a part in determining energy uses in every country include the availability of appropriate technology (which can determine the economics of substitutability among fuels), government policies (which can distort energy markets), environmental concerns (which can affect energy usage and choices), and the geographical distribution of energy resources.

Asia-Pacific countries have been notorious for their distortion of domestic energy prices, which in many cases differ significantly from the internationally traded prices. A forecast of regional energy demand based on international market prices would therefore be inappropriate, and a country-by-country analysis is unavoidable. International energy prices do, however, provide a baseline for projecting an individual country's energy demand, and they are expected to play an even more important role in determining the region's energy demand in the future. The shift toward market-oriented pricing practices is reflected in the recent trends of economic reform and energy pricing reform in the region. In addition, the region's energy imports will increase, and hence there will be greater interaction between domestic energy markets and the international market. For example, currently more than 50 percent of the oil consumed in the region is imported from outside, and imports are expected to become ever larger as the region's oil reserves become depleted.

The relationship between international and domestic energy prices differs from country to country, depending on factors such as the availability of indigenous resources, options for energy supplies, and government policies. A knowledge of such relationships is a prerequisite for projecting energy demand and supply in the region. The following section outlines our views of future world and domestic energy prices, which are the main assumptions underlying our projections for the Asia-Pacific region up to the year 2010.

WORLD ENERGY PRICES

We forecast marker crudes (i.e., Arab Light and Minas) and petroleum products in three scenarios: base case, low case, and high case. The product forecast is based on the Singapore f.o.b. price in constant 1993 U.S. dollars. Singapore has long served as a swing supplier that enables many Asia-Pacific countries to meet their domestic petroleum product demand, and the Singapore f.o.b. prices therefore reflect the regional supply and demand patterns.

From a global point of view, concerns about possible shortages of petroleum resources have been replaced by concerns about the capacity to extract the resources and the environmental impact of consuming them. The base case projections assume steady, coordinated growth in demand, matched by steady growth in production capacity throughout the outlook period. Supply is assumed to become tight with respect to demand, as a result of laxity of capital investment in petroleum exploration and development during the rest of the present decade. The low case projections assume that demand is curbed significantly by environmental legislation in the region's more developed countries. The high case projections assume stronger global economic growth and diminished environmental concerns in petroleum producing countries. In all three cases, it is assumed that prices will move smoothly in relation to the demand-supply balance. Political conflicts or technological breakthroughs are assumed to be too moderate to cause any disruption in market equilibrium.

The price differential between Arab Light and Arab Heavy widened after the Iraqi invasion of Kuwait and remained in the range of $3 to $3.50 per barrel for most of 1991. In 1993, however, it narrowed to about $1 per barrel (see Table 2.2). Our base case scenario assumes that the differential between Arab Light and Arab Heavy will be in the range of $1 to $2 per barrel during the outlook period. The price differential between heavy sweet crudes and heavy sour crudes has narrowed somewhat, as a result of the emergence of new

Table 2.2 Crude prices, 1993, with projections to 2010 (price per barrel in constant 1993 US$)

Scenario and crude	1993	2000	2010
Base case			
Arab Light	14.16	20	27
Arab Heavy	13.19	19	25.7
Minas	17.86	23	29
Low case			
Arab Light	14.16	15	21.5
Arab Heavy	13.19	14	20
Minas	17.86	18	25
High case			
Arab Light	14.16	23	31.5
Arab Heavy	13.19	20.5	29
Minas	17.86	26	35

crude production in the Asia-Pacific region during 1991–94, but it will begin to widen. In addition, the differentials between light sweet crudes and heavy sweet crudes, and those between light sweet crudes and heavy sour crudes, will widen throughout the 1990s. Given the rush to change product specifications and the region's relatively unsophisticated refining complexes, sweet Asian crudes will command premiums over the Middle East crudes (see Figure 2.1).

In recent years, the Asia-Pacific region has experienced an unprecedented demand surge for petroleum products, which has not been accompanied by adequate expansion of the region's refining capacity. The surge has resulted in greater dependence on Singapore as a refining center and has helped to create healthier refining margins in the region. Also, the demand growth patterns are different for each product. As an example, diesel demand has grown more rapidly than demand for other products, and diesel prices have thus grown faster than the prices of other products. In contrast, fuel oil has shown little demand growth, and therefore the price differential has increased between fuel oil and lighter products such as middle distillates and gasoline. Our projections reveal a widening of the differential between light products and fuel oil over time. The trend of moving toward market-oriented pricing, which can be observed in many countries,

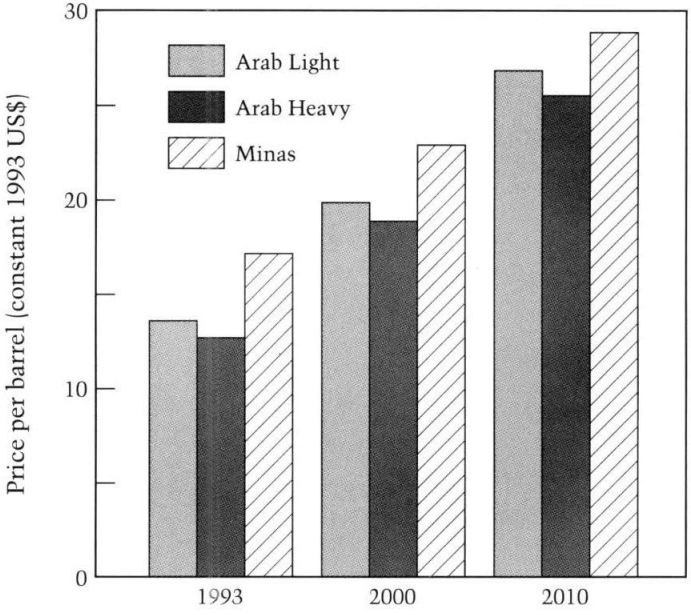


Figure 2.1 Crude price differentials, 1993, with base case projections to 2010

will eventually "correct" price distortions caused by government intervention. Until the end of the century, however, we expect diesel prices to increase at a faster rate than the prices of other fuels (see Table 2.3 and Figure 2.2).

The primary factors influencing coal prices are the supply of and demand for coal, not competition with petroleum. Coal is commonly divided into two major categories: thermal coal and metallurgical coal. Thermal coal sells for about $35 per tonne delivered to coastal power plants in Asia. Although substantial growth in consumption of thermal coal is expected, prices are unlikely to increase significantly in terms of constant 1993 dollars over the longer term, because of strong competition in the coal market. Such competition is expected to remain high during the outlook period, with major suppliers such as Australia, China, and Indonesia offering more coal in the market. Constant prices of $35–40 per tonne of thermal coal are projected for the period from 1993 to 2010, with greater variation in the shorter term.

The quality specifications for metallurgical coal are

Table 2.3 Petroleum product prices, 1993, with projections to 2010 (price per barrel in constant 1993 US$)

Scenario and product	1993	2000	2010
Base case			
Naphtha	17.17	25.10	33.00
Mogas (97 RON unleaded)	23.06	29.85	37.25
Kero/jet	23.45	32.85	37.25
Diesel (0.5% S)	23.06	33.35	36.90
HSFO (380 CST)	10.61	13.45	19.90
LSWR	14.27	17.45	24.90
Low case			
Naphtha	17.17	20.10	27.10
Mogas (97 RON unleaded)	23.06	24.85	31.35
Kero/jet	23.45	25.55	31.55
Diesel (0.5% S)	23.06	25.35	31.35
HSFO (380 CST)	10.61	8.45	14.95
LSWR	14.27	12.45	18.95
High case			
Naphtha	17.17	28.10	37.10
Mogas (97 RON unleaded)	23.06	32.85	41.35
Kero/jet	23.45	37.05	42.55
Diesel (0.5% S)	23.06	37.85	42.35
HSFO (380 CST)	10.61	16.45	24.95
LSWR	14.27	20.45	28.95

tighter than those for thermal coal, and prices of metallurgical coal on average are at least $10 per tonne higher than those of thermal coal. China is the only country in the world that is expected to have demand growth in metallurgical coal, and this growing demand will probably be met by domestic supplies. Because of stagnant demand, metallurgical coal prices are not expected to increase in constant 1993 dollars during the outlook period.

Much of the natural gas trade in the Asia-Pacific region—unlike that of North America and Europe—has been, and will continue to be, in the form of LNG, since few international gas pipelines exist in this region. The nature of the LNG trade—which requires highly capital intensive supply trains, specialized marine transport carriers, and fixed receiving and degasification terminals—binds buyer and seller in a closer relationship than the pipeline gas trade does. Since LNG is delivered under long term contracts, there is no spot

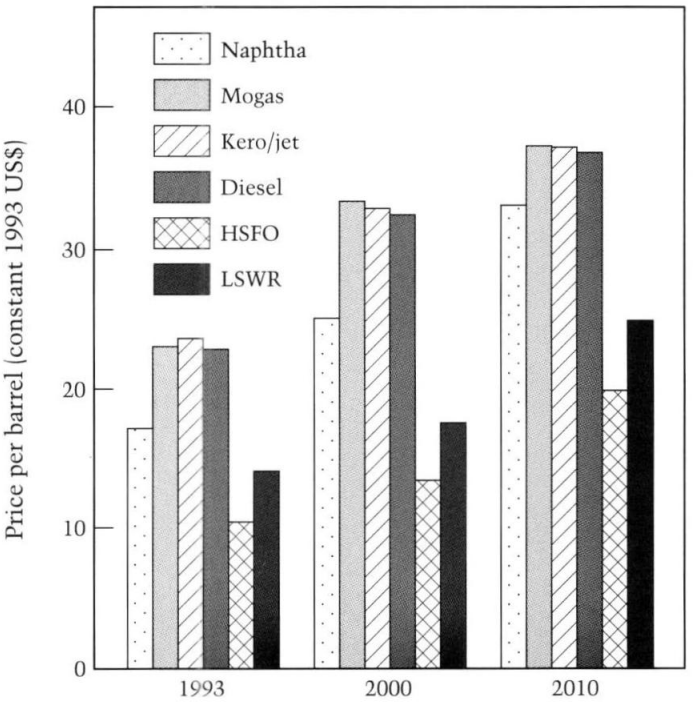


Figure 2.2 Petroleum product prices, 1993, with base case projections to 2010

market and hence no quoted market price. The price specified in each contract is the outcome of bilateral negotiations, and therefore both price and demand are determined simultaneously. Although the negotiated LNG prices are indexed to crude oil prices in one way or another, the debate continues about whether LNG can be priced in relation to something besides crude oil and whether trading in spot cargoes will pick up. We assume that LNG will remain dependent on oil prices at least until the first decade of the next century and that LNG prices will increase in proportion to crude oil prices. An LNG price increase will be necessary, however, to make future grass-roots LNG projects economically viable.

DOMESTIC ENERGY PRICES

Some governments in the Asia-Pacific region still maintain regulations that keep domestic energy prices below world

prices. Their energy pricing policies are mostly based on sociopolitical considerations. One common practice is a subsidy, in which the government sets the prices of selected petroleum products below market prices and then pays the difference. A second practice is a cross-subsidy among products, in which the government sets a high price for one product to compensate for low prices charged for other products. A cross-subsidy policy often translates into the familiar pattern in which low prices are maintained, for example, for kerosene (because the poor use it for cooking) and for industrial fuels (including diesel and fuel oil, to promote development), whereas prices are much higher for gasoline and jet fuel (since they are considered luxuries). Such practices partly explain the differences in consumption patterns across the barrel in the Asia-Pacific region. Also, such policies are partly responsible for the relatively strong consumption growth of some products, including the massive demand for diesel that has emerged in many countries.

Strong economic development in both the newly industrialized and the developing economies has been accompanied by rapid increases in petroleum product consumption. In most cases, domestic refinery expansions have been inadequate to cope with the increased demand—not to mention the technical modifications necessary to adapt to Middle East crudes and the restraints imposed by increasingly stringent product specifications. Imports have been particularly problematic, since domestic prices are usually lower than international prices, and the price differentials exacerbate current account deficits. Moreover, the differences in demand growth have driven up the prices of certain products and thus changed price differentials.

A current trend in most Asia-Pacific countries is to reduce regulations that inhibit market forces in the energy sector. Some of the more developed economies, such as Hong Kong, Japan, New Zealand, and Singapore, already rely on a free-market pricing system. In these economies, increasingly restrictive environmental regulations are likely to have the greatest impact on energy prices. Most of the other countries

either are decreasing the regulation of energy pricing or have plans to do so in the near future (see Table 2.4). Australia does not regulate any energy prices other than those of natural gas and electricity, and plans are currently being formulated to reduce the restrictions on these two forms of energy. In China, price controls on coal were removed in 1994. China still controls all other energy prices, but it has been moving domestic petroleum prices to market price levels and has, in fact, fixed wholesale prices above the international market levels. The policy announced in Taiwan in 1991 is that energy prices should be determined on the basis of costs. Although Taiwan's energy prices are still regulated, cost-based pricing introduces a significant tie to market pricing.

Thailand has deregulated domestic oil and petroleum product prices, with the exception of LPG. The deregulation process was divided into two stages. A "semi-floating" price system was introduced in May 1991 by deregulating retail prices and the marketing margin. Controls were retained on ex-refinery prices in this stage, but once the revamped domestic oil market began to function well, ex-refinery prices were deregulated in August 1991. The Philippine government

Table 2.4 Regulation of retail energy prices

	Petroleum products								
Economy	LPG	Gaso-line	Kero/jet	Diesel	Fuel oil	Oil	Gas	Coal	Elec-tricity
Australia	no	no	no	yes	no	no	yes	no	yes
Brunei	yes	yes	yes	yes	yes	yes	yes	na	yes
China	yes	yes	yes	yes	yes	yes	yes	no	yes
Hong Kong	no	no	no	no	no	no	no	no	yes
Indonesia	yes	yes	yes	yes	yes	yes	yes	no	yes
Japan	no	no	no	no	no	no	no	no	yes
Korea	yes	yes	yes	yes	yes	yes	yes	yes	yes
Malaysia	yes	yes	yes	yes	yes	no	no	no	yes
New Zealand	no	no	no	no	no	no	no	no	no
Papua New Guinea	yes	yes	yes	yes	yes	yes	na	na	yes
Philippines	yes	yes	yes	yes	yes	no	na	no	yes
Singapore	no	no	no	no	no	no	yes	na	yes
Taiwan	yes	yes	yes	yes	yes	yes	yes	no	yes
Thailand	yes	no	no	no	no	no	no	no	yes

na = not applicable.

is planning a similar deregulation process but has not yet scheduled its implementation. The Malaysian approach is slightly different: retail consumer products (including gasoline, diesel, and household LPG) are regulated, although closely tied to the market, whereas wholesale diesel, fuel oil, and jet fuel are sold at negotiated or market contract prices. The Korean government has used the price stabilization fund model to regulate prices and correct what it perceived to be the inefficiencies of direct market pricing. Korea has gradually reduced its pricing regulations since 1993, when controls on jet fuel and solvents were lifted. In its latest round of policy changes, product prices have been adjusted monthly since February 1994, based on international prices and exchange rates.

Indonesia's system of cross-subsidizing fuel prices has become very costly: $450 million in fiscal year 1991/92 alone. Instead of deregulating, Indonesia has taken a different approach. The government is introducing coal briquettes for cooking, to displace demand for kerosene among low income groups. Once the alternative is in place, the price of kerosene will be increased. While this procedure is expected to improve the pricing balance, it is not expected to solve the problem completely.

At the other end of the spectrum, neither Papua New Guinea nor Brunei has plans to deregulate energy prices. The government of Papua New Guinea is actually increasing its regulation of pricing, with the goal of reducing the urban-rural price imbalance. Brunei, on the other hand, enjoys a unique position in the region. Its prices are regulated by the government, but they are very close to market prices. Taxes are so low that they are practically nonexistent. This situation exists because Brunei is a small, relatively rich oil-exporting country and does not need to tax petroleum products.

A brief summary is provided in Tables 2.5 to 2.8 of prices and tax elements of petroleum products, natural gas, coal, and electricity in selected Asia-Pacific countries in January 1994. As Table 2.6 illustrates, prices vary greatly from country to country. For example, the prices of a barrel of LPG

Table 2.5 Consumer (end user) prices of petroleum products, January 1994 (US$ per barrel)

Product	Australia	Brunei	China	Taiwan	Indonesia	Japan	Korea	Malaysia	New Zealand	Papua New Guinea	Philippines	Singapore	Thailand
LPG	24.94	41.73				30.96	10.23	68.71		23.37	30.05		33.17
						(3.37)	(3.37)	(0.58)			(5.72)		
Gasoline													
Unleaded regular	69.45			90.73		183.92	121.47		79.00			104.07	
	(39.32)			(40.86)		(80.06)	(70.88)		(38.20)			(56.33)	
Unleaded premium	74.94	52.66	45.24	96.74	55.65	196.76	148.46	64.05				110.59	62.58
	(38.96)	(0.53)	(14.39)	(43.56)	(5.56)	(80.06)	(85.47)	(28.65)				(59.52)	(2.49)
Leaded regular		34.98	44.43				121.47	61.72			54.32		47.91
		(0.53)	(14.13)				(67.57)	(32.78)			(18.75)		(3.17)
Leaded premium	69.35	52.66		96.74			156.34	65.80	83.47	80.26	57.18	122.55	
	(39.27)	(0.52)		(43.56)			(67.57)	(32.78)	(40.62)		(20.13)	(74.12)	
Naphtha						16.46	16.46						
						(3.36)	(1.50)						
Kerosene	70.28	19.67	47.16		22.26	69.86	49.76	37.96		72.41	40.02		
	(9.41)	(0.52)	(14.15)		(2.23)	(3.36)	(8.09)	(6.87)			(8.58)		
Diesel													
Automotive diesel	65.59	30.60	39.46	68.50	30.21	119.76	42.71	37.38	40.62	62.44	40.02	47.83	45.42
	(35.64)	(0.53)	(12.23)	(27.22)	(3.02)	(49.12)	(6.55)	(7.69)	(4.83)		(8.29)	(8.54)	(2.24)
Industrial diesel	42.85				28.62	85.97	41.53			52.96	36.92		
	(30.38)				(2.86)	(3.36)	(9.74)				(8.29)		
Power sector diesel					30.21	36.07	36.64	38.49			36.92		
					(3.02)	(3.36)	(9.11)	(7.69)			(8.29)		
Marine diesel	51.80				30.21	37.50	26.78	17.17		52.96	36.92		
					(3.02)	(3.36)	(2.73)	(7.69)			(8.29)		

Fuel Oil										
Low sulfur small industrial			22.80 (1.55)		30.18 (3.36)	20.03 (1.82)	15.26 (0.92)		22.72	
Low sulfur large industrial	24.13 (6.91)				27.33 (3.36)	18.11 (1.65)	15.26 (0.92)	35.67 (3.96)	26.32	
Low sulfur power sector					27.26 (3.36)	18.11 (1.65)	14.67 (0.92)		19.61	
High sulfur small industrial				23.85 (2.38)	23.10 (0.00)	16.13 (1.47)	13.80 (0.92)			15.16 (5.72)
High sulfur large industrial	21.51			23.85 (2.38)	20.25 (0.00)	14.41 (1.31)	13.80 (0.92)	27.85 (3.10)		15.16 (5.72)
High sulfur power sector				23.85 (2.38)	20.17 (0.00)	14.41 (1.31)	11.70 (0.92)			15.16 (5.72)

Note: New Zealand prices are for the first quarter of 1994, not January 1994. Figures in parentheses are the tax elements in total prices. Blank spaces have been left where data are unavailable.

Table 2.6 Consumer (end user) prices of natural gas, January 1994 (US$ per million cubic feet)

Economy	Residential		Commercial		Industrial		Power sector	
	Total price	Tax element	Total price	Tax element	Total price	Tax element	Total price	Tax element
Brunei	1.12						0.28	
Taiwan	7.16	0.47	7.16	0.47				
Indonesia	1.02		2.04		1.02		2.58	
Japan	25.60	8.76					9.58	3.65
Korea	10.31	1.03	10.64	0.80	6.77	0.68	5.88	
Malaysia	8.30		7.78		5.19		4.15	
New Zealand	11.00	1.66					7.70	

Note: New Zealand prices are for the first quarter of 1994, not January 1994. Total price refers to price including tax. Blank spaces have been left where data are unavailable.

Table 2.7 Consumer (end user) prices of coal, January 1994 (US$ per tonne)

Economy	Residential		Large industrial		Power sector	
	Total price	Tax element	Total price	Tax element	Total price	Tax element
China	26.61					
Indonesia			27.62		29.03	
Japan			54.40	1.60	63.40	1.60
Korea	77.14		45.54		38.47	
Malaysia			31.49		31.49	
Philippines			34.26		33.60	

Note: Total price refers to price including tax. Blank spaces have been left where data are unavailable.

Table 2.8 Consumer (end user) prices of electricity, January 1994 (US$ per kilowatt hour)

	Residential		Commercial		Industrial	
	Total price	Tax element	Total price	Tax element	Total price	Tax element
China	0.03		0.05		0.04	
Indonesia	0.06		0.12		0.05	
Japan	0.62	0.40	0.61	0.40	0.52	0.40
Korea	0.11	0.01	0.10	0.01	0.06	0.01
Malaysia	0.08		0.13		0.04	
New Zealand	0.07	0.10	0.07		0.03	
Papua New Guinea	0.17		0.19		0.13	
Philippines	0.10		0.10		0.10	
Singapore	0.08		0.05		0.05	

Note: New Zealand prices are for the first quarter of 1994, not January 1994. Total price refers to price including tax. Blank spaces have been left where data are unavailable.

range from $10.23 in South Korea to $41.73 in Brunei; for a barrel of unleaded premium gasoline, the prices range from $52.66 in Brunei to $196.76 in Japan. Different groups of consumers are usually charged different prices for natural gas, coal, and electricity. In general, Japan has the highest energy prices, whereas Brunei has the lowest ones. The highest priced product is gasoline, and the lowest priced is fuel oil. The tax element is a crucial contributor to high energy prices and is the main reason for the product price differentials among countries.

The regional trend is clearly toward a less regulated energy sector, although the extent of deregulation varies significantly from country to country. Transition is not always easy, but the dominance of market prices will make the region more competitive in the long run.

ELECTRIC POWER GENERATION ASSUMPTIONS

Our forecast for the electric power sector covers sixteen major Asia-Pacific economies (as defined in chapter 1) and seven Pacific island economies, grouped as follows: OECD Pacific, newly industrialized economies, Southeast Asian countries, South Asian countries, China, and the Pacific Islands. The Pacific Islands covered by the forecast are the Cook Islands, Fiji, Papua New Guinea, the Solomon Islands, Tonga, Vanuatu, and Western Samoa. The data in the study cover only the public utilities and not the cogenerators.

The projection of total power generation is based on the forecast demand for electricity which, in turn, is tied closely to growth rates of GDP. Factors such as system losses, the potential to import electricity from a neighboring country, and the possibility of purchasing electricity domestically from private generation are taken into account to adjust the projection of electricity generated. Total installed capacity is estimated from projected peak demand and planned reserve margin. Peak demand is assumed to grow slightly faster than GDP. Generation by energy source is projected by estimating the average annual capacity utilization of each type of power plant serving base, intermediate, or peak load. In general, it

is assumed that coal fired and nuclear plants will be used to serve base load and that intermediate and peak loads will be served by oil fired, gas fired, and hydroelectric plants. These uses will vary among countries, however, depending on factors such as an individual country's resource endowment, government policy, and energy prices. Average annual capacity utilization is assumed to vary in the ranges of 65–70 percent for base load, 20–50 percent for intermediate load, and 5–15 percent for peak load.

Total installed capacity in the Asia-Pacific region is projected at 942.9 GW in 2000 and 1,598.7 GW in 2010, compared with 602.7 GW in 1993. Average annual growth rates of total installed capacity are forecast at 6.6 percent from 1993 to 2000 and 5.4 percent from 2000 to 2010. The overall average from 1993 to 2010 will thus be 5.9 percent, compared with 5.6 percent from 1980 to 1990. Such rapid capacity growth during the outlook period will be facilitated by the implementation of privatization policies in the power sectors of many countries.

Most of the capacity additions in the region during the outlook period will be thermal power plants. Coal will be the main fuel used for power generation in the region. Substantial expansion of coal fired capacity is expected in Southeast Asia, especially in Indonesia and Thailand. Coal fired capacity is projected to increase at average annual rates of 9.3 percent during 1993–2000 and 6.1 percent during 2000–

Table 2.9 Shares of Asia-Pacific installed electric power capacity by energy source, 1993, with projections to 2010

	Share of total installed capacity (%)		
Energy source	1993	2000	2010
Oil	17.5	11.4	7.7
Gas	13.1	14.2	14.4
Coal	37.3	44.4	47.2
Hydro	22.6	21.2	20.1
Nuclear	9.2	8.2	9.7
Geothermal	0.3	0.4	0.6
Other renewable	0.0	0.1	0.2

Note: Throughout the tables, sums of individual data do not necessarily equal the totals because of rounding errors.

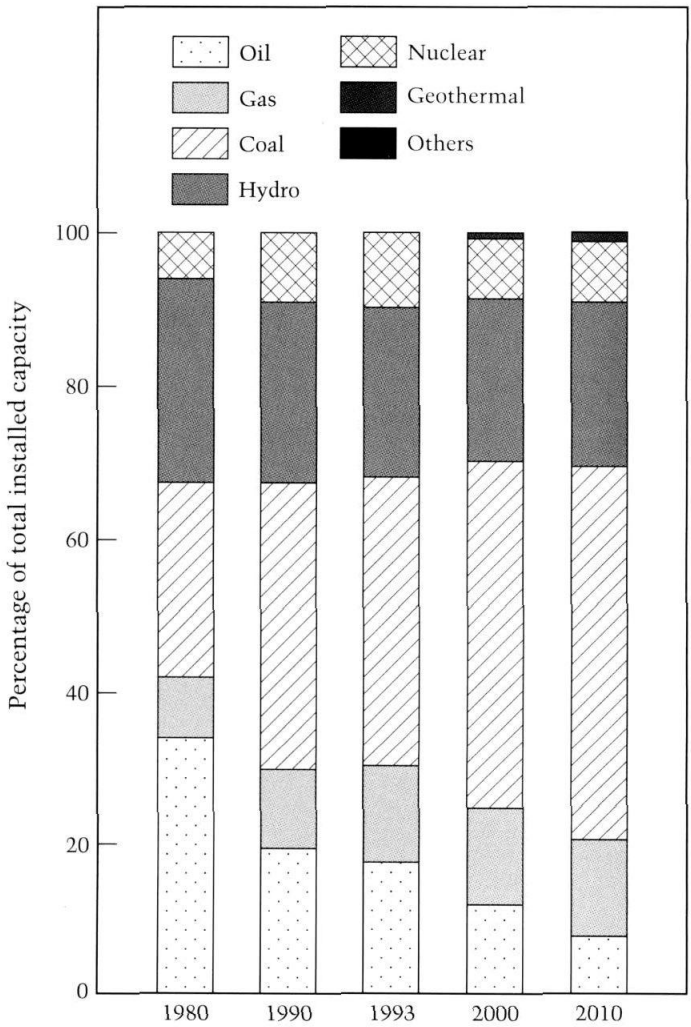


Figure 2.3 Shares of Asia-Pacific installed power capacity by energy source, 1980–93, with projections to 2010

2010. It will increase from 37.3 percent of total capacity in 1993 to 44.4 percent in 2000 and 47.2 percent in 2010. The share of gas fired capacity in total capacity will rise from 13.1 percent in 1993 to 14.2 percent in 2000 and 14.4 percent in 2010. In contrast, the oil fired share will decline from 17.5 percent in 1993 to 11.4 percent in 2000 and only 7.7 percent in 2010, since most countries in the region are switching to coal and gas for power generation (see Table 2.9 and Figure 2.3).

The projected installed capacities in the Asia-Pacific region are outlined in Figure 2.4 and Table 2.10 by energy source. The region's installed nuclear capacity in 1993 was 55.3 GW, and China, India, Japan, Pakistan, South Korea, and Taiwan are planning to bring more nuclear units on line. Although their official pronouncements add up to a very large total for new nuclear capacity by 2010, the actual nuclear additions will be less than the official plans, because of public resistance to nuclear expansion and the slow growth rate of the Japanese economy. We forecast that installed nuclear capacity in the region will increase at an average annual rate of about 5.0 percent during 1993–2000 and 7.1 percent during 2000–2010. A major increase is expected in Japan, which plans to add 6.7 GW during 1993–2000 and a further 24.9 GW during 2000–2010. China plans to add 19.6 GW by 2010. Most of the remaining nuclear capacity additions in the re-

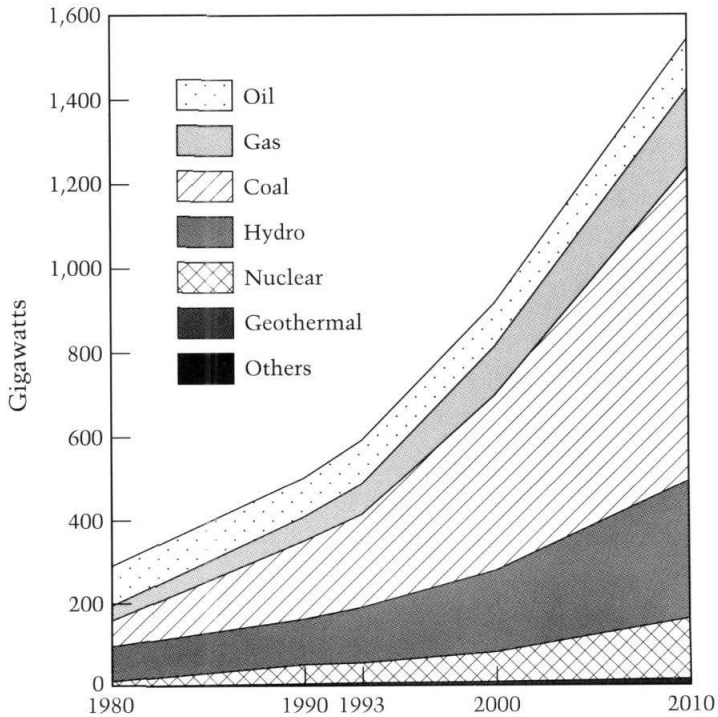


Figure 2.4 Asia-Pacific installed power capacity by energy source, 1980–93, with projections to 2010

Table 2.10 Installed electric power capacity by energy source, 1993, with projections to 2010

Energy source	Installed capacity (gigawatts)			Growth rate (%)		
	1993	2000	2010	1993–2000	2000–2010	1993–2010
Oil total	105.2	107.7	123.5	0.3	1.4	0.9
OECD Pacific	56.4	54.5	46.8	-0.5	-1.5	-1.1
NIEs	16.5	19.8	25.2	2.6	2.4	2.5
Southeast Asia	14.3	13.7	15.5	-0.6	1.2	0.5
South Asia	4.9	7.7	10.9	6.7	3.5	4.8
China	12.9	11.7	24.6	-1.4	7.7	3.9
Pacific Islands	0.2	0.3	0.5	2.7	5.5	4.4
Gas total	78.8	133.6	230.2	7.8	5.6	6.5
OECD Pacific	47.0	67.1	72.5	5.2	0.8	2.6
NIEs	8.7	17.5	33.1	10.5	6.6	8.2
Southeast Asia	11.1	17.9	52.0	7.1	11.3	9.5
South Asia	9.0	23.6	40.1	14.8	5.4	9.2
China	3.0	7.5	32.5	14.0	15.8	15.0
Pacific Islands	0.0	0.0	0.0	na	na	na
Coal total	225.0	418.6	754.7	9.3	6.1	7.4
OECD Pacific	40.2	58.8	76.6	5.6	2.7	3.9
NIEs	17.5	26.3	39.3	6.0	4.1	4.9
Southeast Asia	5.3	28.7	63.6	27.3	8.3	15.7
South Asia	44.0	85.4	164.1	9.9	6.7	8.1
China	118.0	219.4	411.1	9.3	6.5	7.6
Pacific Islands	0.0	0.0	0.0	na	na	na
Hydro total	136.2	199.9	321.2	5.6	4.9	5.2
OECD Pacific	51.0	58.0	70.5	1.9	2.0	1.9
NIEs	5.1	8.4	12.4	7.4	4.0	5.4
Southeast Asia	8.5	13.4	22.5	6.7	5.3	5.9
South Asia	26.3	56.6	78.4	11.6	3.3	6.6
China	45.0	63.2	137.0	5.0	8.0	6.8
Pacific Islands	0.3	0.3	0.4	1.3	3.3	2.5
Nuclear total	55.3	77.7	155.0	5.0	7.1	6.3
OECD Pacific	38.4	45.1	70.0	2.3	4.5	3.6
NIEs	12.8	19.9	35.6	6.5	6.0	6.2
Southeast Asia	0.0	0.0	0.0	na	na	na
South Asia	2.0	10.0	27.1	25.8	10.5	16.6
China	2.1	2.7	22.3	3.7	23.5	14.9
Pacific Islands	0.0	0.0	0.0	na	na	na
Geothermal total	2.0	4.1	10.2	10.8	9.5	10.1
OECD Pacific	0.6	0.8	3.1	4.2	14.5	10.1
NIEs	0.0	0.0	0.0	na	na	na
Southeast Asia	1.4	3.3	7.1	13.0	8.0	10.0
South Asia	0.0	0.0	0.0	na	na	na
China	0.0	0.0	0.0	na	na	na
Pacific Islands	0.0	0.0	0.0	na	na	na
Other renewable total	0.2	1.3	3.8	30.7	11.3	18.9
OECD Pacific	0.0	0.5	1.8	na	13.7	na
NIEs	0.0	0.0	0.0	na	na	na
Southeast Asia	0.0	0.0	0.0	na	na	na
South Asia	0.2	0.8	2.0	21.9	9.6	14.5
China	0.0	0.0	0.0	na	na	na
Pacific Islands	0.0	0.0	0.0	na	na	na
Total capacity	602.7	942.9	1,598.6	6.6	5.4	5.9

Note: Rounding errors occur.
na = not applicable.

gion during the outlook period will be in India (17.5 GW), South Korea (16.9 GW), Pakistan (7.6 GW), and Taiwan (6.0 GW). In addition, North Korea has a nuclear program, and Indonesia hopes to bring its first nuclear plant (0.6 GW) on line by 2003.

In 1993 the Asia-Pacific region had a total of 136.2 GW of hydro capacity, 76 percent of which was in Japan, India, and China. The projected additions of 63.7 GW by 2000 and a further 121.3 GW by 2010 imply average annual growth rates of 5.6 percent during 1993–2000 and 4.9 percent during 2000–2010. The major capacity additions will be in the South Asian countries.

Geothermal capacity is currently a very small proportion (less than 1%) of the region's total installed capacity. Expansions planned in Indonesia and the Philippines will increase installed geothermal capacity at rapid annual average rates of 10.8 percent during 1993–2000 and 9.5 percent during 2000–2010. Since this increase is built on such a small base, however, the geothermal share of total installed capacity will remain very small.

The installed capacity of plants using other renewable forms of energy (such as waste fired, photovoltaic, and wind power) was 0.2 GW in 1993. It is expected to increase to 1.3 GW in 2000 and 3.8 GW in 2010, as a result of capacity additions in India and Japan. These renewable resources will represent about 0.1 percent of the region's total capacity in 2000 and 0.2 percent in 2010.

During the outlook period, the utilities in the region are expected to improve efficiencies in power generation. It is assumed that system losses (which include auxiliary use and transmission and distribution losses) will tend to decline in most countries and that, in the other countries, such losses will be no worse than the current levels (see Table 2.11). The percentage of auxiliary use in total generation is assumed to remain constant; reductions in system losses will therefore be the result of improvements that reduce transmission and distribution losses. In addition, it is assumed that the imple-

Table 2.11 Total power system losses, 1980–93, with projections to 2010 (% of gross generation)

Economic group	1980	1990	1993	2000	2010
OECD Pacific	12.6	10.7	11.1	11.0	11.0
NIEs	12.0	10.4	10.0	10.0	10.0
South Asia	29.6	27.8	27.6	23.2	19.5
Southeast Asia	18.6	18.3	17.9	16.3	15.6
China	13.8	13.1	12.5	12.0	12.0
Pacific Islands	12.6	10.3	10.7	10.5	10.1

mentation of demand-side management programs by the countries in the region will result in lower growth rates of energy consumption.

Energy Supply and Demand to 2010

The Asia-Pacific region has the most rapidly growing energy demand in the world and will continue to have an increasing impact on world energy demand. Given the heterogeneity of economies in the region, any regional demand analysis has to be constructed country by country. In undertaking the demand forecasts provided in this study, scenarios were developed for high, low, and base cases that take into account variations in economic performance, prices, and fuel substitution in individual nations and in the region as a whole. China is included in the aggregate regional data provided in this chapter. Data from the countries of the former Soviet Union are not included in the regional totals in this chapter and are discussed separately in chapter 4.

INTRODUCTION

Issues of particular importance to the Asia-Pacific region include the supply and demand balance of energy resources and the substitutability of fuels. In addition, national policies are often driven by price and supply security (which are assessed at the national level) and by investment and development strategies at the national, regional, and international levels. These factors have been integrated, where appropriate, in the demand projections of this study. Substitution of gas and coal for many uses of oil is a major ongoing change that is difficult to predict in detail, but the general trends of increased gas and coal use are definable and have been used in evaluating potential demand modifications. Although the substitution of natural gas and (to a lesser extent) coal for oil is desirable and is proceeding throughout the region, the cost of the infrastructure required for gas transmission will be a major constraint on gas utilization and substitution.

Electricity growth in the Asia-Pacific region will be a major determinant in defining demand for coal. Coal demand and supply are dominated by four nations: Australia, China, India, and Japan. In assessing coal utilization and the potential for substitution, therefore, our demand projections are strongly influenced by the policies of these four nations. The uses of hydro, nuclear, and geothermal power as alternatives to fossil fuels for electricity generation are also examined.

OIL

OIL DEMAND

The Asia-Pacific region is the only part of the world that has produced major new demand in the world oil market in recent years. Between 1990 and 1993, the region's demand rose by 3.0 million barrels per day (mmb/d). This new demand more than offset the declining demand in other regions and consequently brought about a net increase of 0.5 mmb/d in global oil demand during this period.

The center of gravity of the world oil market has shifted to the Asia-Pacific region. Given the size of the region's population—about 3 billion people, or nearly 60 percent of the total world population—the region has great potential to expand oil demand. The region's impressive economic growth in recent years is expected to continue during the next decade, and the region will therefore continue to have the world's highest growth rate of oil demand. The region's oil demand has already surpassed Western Europe's and will soon overtake North America's.

There are two basic approaches to demand forecasting: top-down and bottom-up. The top-down approach considers large-scale economic factors, such as world GDP, levels of global trade, world inflation, and average energy intensity, and then allocates some assumed oil/GDP ratio to each region of the world. The bottom-up approach is on a country-by-country and product-by-product basis, and pays attention to features such as end uses of fuels, government policies,

capital stock and infrastructure, and related sociopolitical factors.

The approach taken here is bottom-up, on a country-by-country basis. The forecast takes into consideration economic factors such as energy prices, energy end uses, and macroeconomic performance, as well as idiosyncratic factors such as foreign-exchange constraints, government policies, and infrastructural constraints. For each country, special attention is paid to the following four factors:

- Economic performance: The country's stage of economic development, growth rate of GDP, and foreign trade will affect energy intensity, end use patterns, and the affordability and availability of energy in the country.
- International oil prices: International oil prices have direct impacts on oil demand and energy policies of oil importing countries.
- Domestic oil pricing: The domestic product-pricing regime plays a major role in shaping domestic demand.
- Substitution: The availability of indigenous energy resources provides substitution potential and increases the country's energy options.

The choice of the bottom-up, country-by-country approach is based on the following considerations. First, the Asia-Pacific region differs from regions such as Western Europe and North America, where oil markets are integrated, levels of economic development are similar, and political systems and energy-related policies are comparable. In contrast, Asia-Pacific political systems are diverse, and the region spans the entire spectrum of economic, social, and demographic development. The stages of development in the region range from the highest tier of industrialization (Japan) and the newly industrialized economies (Hong Kong, Taiwan, Singapore, and South Korea) to countries in which per capita GDP is less than US$500 (China, India, and Nepal, for example). The overall economic growth of the region during the past decade has been stronger than the world average.

The performance of individual economies, however, has ranged from those with double-digit growth rates to those with less than moderate growth.

In addition, the economies in the region vary significantly in both energy resources and energy consumption patterns. Some, such as Australia, China, Indonesia, and Malaysia, have rich hydrocarbon endowments, whereas others, such as Japan, Singapore, South Korea, and Taiwan, have to import almost all of their oil. Energy consumption patterns among countries in the region differ in several ways. For example, China's oil consumption accounts for less than 20 percent of its total energy consumption, whereas more than 55 percent of Japan's energy consumption is in the form of crude oil and oil products. China's income elasticity of energy demand has been in the range of 0.5–0.6 for many years, reflecting the fact that energy demand has been growing at a much slower pace than the country's economic growth. In some countries, however, energy demand growth has outpaced economic growth. A comparison of energy intensities would not be very relevant in this region, because many of the region's currencies are not fully convertible. Moreover, oil markets have not fully liberalized in most countries in the region; many Asia-Pacific governments intervene in their domestic petroleum markets with a variety of policies that affect or determine product pricing, subsidies, and the regulation of imports through import taxes or quotas.

Scenarios of oil product demand for the outlook period are presented in Table 3.1. In the base case scenario, oil product demand (excluding direct burning of crude in China and Japan) will increase from 14.9 mmb/d in 1993 to 19.8 mmb/d in 2000 and 26.6 mmb/d in 2010, and average annual growth rates will be 4.1 percent during 1993–2000 and 3.0 percent during 2000–2010. For the high case scenario, the regional oil product demand is projected to increase at average annual rates of 5.0 percent from 1993 to 2000 and 3.5 percent from 2000 to 2010; for the low case scenario, the projections are 3.5 percent and 2.5 percent, respectively (see Figure 3.1).

Table 3.1 Oil product demand, 1980–93, with projections to 2010

Scenario and item	Demand (thousand barrels per day)					Growth rate (%)				
	1980	1990	1993	2000	2010	1980–1990	1990–1993	1993–2000	2000–2010	1993–2010
Base case	10,158	12,358	14,935	19,787	26,570	2.0	6.5	4.1	3.0	3.4
By product										
LPG	633	1,033	1,263	1,696	2,251	5.0	6.9	4.3	2.9	3.5
Gasoline	1,453	2,168	2,609	3,719	5,597	4.1	6.4	5.2	4.2	4.6
Naphtha	629	932	1,257	1,754	2,245	4.0	10.5	4.9	2.5	3.5
Kero/jet	1,094	1,383	1,617	2,258	3,073	2.4	5.3	4.9	3.1	3.8
Diesel	2,113	3,494	4,529	6,306	8,928	5.2	9.0	4.8	3.5	4.1
Fuel Oil	3,836	2,833	3,095	3,383	3,683	–3.0	3.0	1.3	0.9	1.0
Others	400	515	565	671	794	2.6	3.1	2.5	1.7	2.0
By consumer										
Australia	630	667	678	780	922	0.6	0.5	2.0	1.7	1.8
China	1,489	2,043	2,678	3,876	6,288	3.2	9.4	5.4	5.0	5.1
India	626	1,095	1,343	1,886	2,750	5.8	7.0	5.0	3.8	4.3
Indonesia	408	610	764	1,247	1,942	4.1	7.8	7.3	4.5	5.6
Japan	4,741	4,481	4,659	5,093	5,139	–0.6	1.3	1.3	0.1	0.6
South Korea	508	980	1,646	2,382	2,886	6.8	18.9	5.4	1.9	3.4
Taiwan	392	549	647	887	1,203	3.4	5.6	4.6	3.1	3.7
Thailand	224	402	564	985	1,689	6.0	11.9	8.3	5.5	6.7
Others	1,140	1,532	1,956	2,651	3,750	3.0	8.5	4.4	3.5	3.9
High case	–	–	–	21,015	29,644	–	–	5.0	3.5	4.1
Low case	–	–	–	19,001	24,324	–	–	3.5	2.5	2.9

Note: Rounding errors occur.

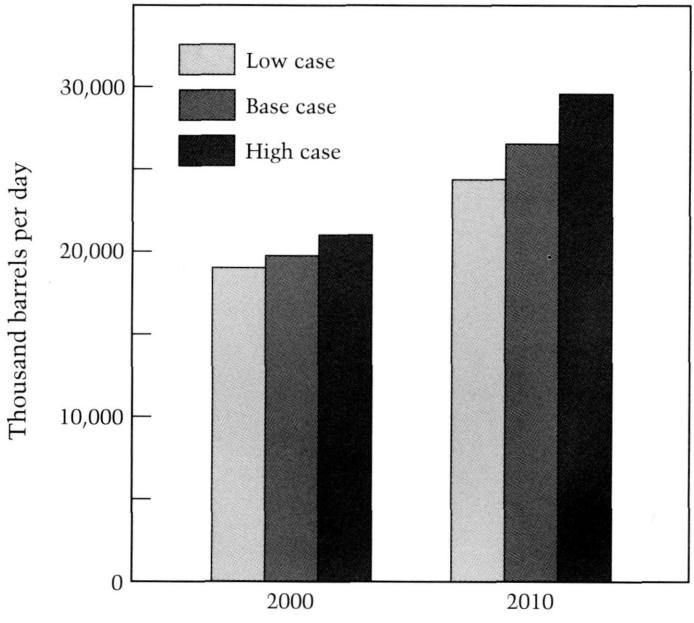


Figure 3.1 Asia-Pacific oil product demand: base, low, and high cases, 2000 and 2010

The demand pattern will continue to skew toward lighter oil products, because of the rapid expansion of road transportation. At the same time, the demand for fuel oil will be dampened by the availability of substitutes—especially natural gas, which is becoming increasingly important as a fuel for power generation (see Figure 3.2). The diesel share of total product demand is expected to increase from 30.3 percent in 1993 to 31.9 percent in 2000 and 33.6 percent in 2010. The gasoline share will increase from 17.5 percent in 1993 to 18.8 percent in 2000 and 21.1 percent in 2010 (see Table 3.2). Gasoline, however, will have the highest average annual growth rate (4.6%) from 1993 to 2010, followed by diesel at 4.1 percent (see Table 3.1). Since the fuel oil growth rate during this period is projected at only 1.0 percent, the share of fuel oil in total product demand will decline from 20.7 percent in 1993 to 17.1 percent in 2000 and 13.9 percent in 2010.

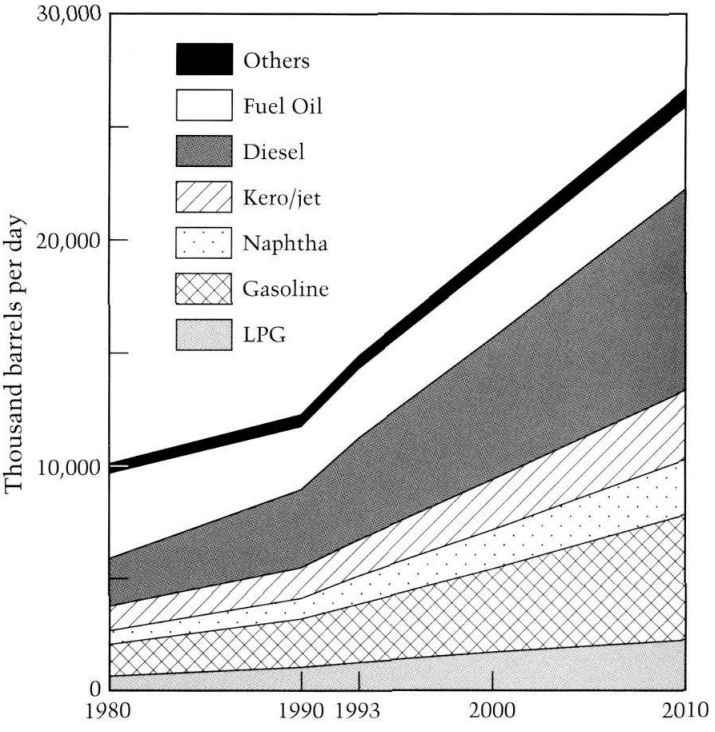


Figure 3.2 Asia-Pacific oil product demand by type of product, 1980–93, with projections to 2010

Table 3.2 Shares of Asia-Pacific oil product demand, 1980–93, with projections to 2010 (%)

Product	1980	1990	1993	2000	2010
LPG	6.2	8.4	8.5	8.6	8.5
Gasoline	14.3	17.5	17.5	18.8	21.1
Naphtha	6.2	7.5	8.4	8.9	8.4
Kero/jet	10.8	11.2	10.8	11.4	11.6
Diesel	20.8	28.3	30.3	31.9	33.6
Fuel oil	37.8	22.9	20.7	17.1	13.9
Others	3.9	4.2	3.8	3.4	3.0
Total	100.0	100.0	100.0	100.0	100.0

Note: Rounding errors occur.

OIL SUPPLY

From the global viewpoint, the Asia-Pacific region has a relatively small oil resource base. Proven oil reserves at the end

of 1993 were about 44.6 billion barrels (Table 3.3), which was about 4.5 percent of the world total. More than 80 percent of the region's proven reserves are in only three countries: China, India, and Indonesia. In terms of production volumes, China is the biggest producer, and the other major producers are Indonesia, Malaysia, India, Australia, Brunei, and Vietnam. The region produced 6.7 mmb/d in 1993, and the reserves-to-production ratio (currently about eighteen years) is well below the world average of forty-six years and far below the Middle East average of 104 years.

From 1970 to 1993, oil consumption in the region grew at an annual average rate of 3.5 percent, whereas the region's crude oil production grew at a rate of 7.0 percent. Consequently, consumption more than doubled from 1970 to 1993, but production was nearly five times greater in 1993 than it was in 1970. The big advances in production, however, were made in the 1970s, when major new greenfield territories were opened for exploration. Although production will continue to grow until the turn of the century, the rate of increase will be lower than in the past. Furthermore, many Asia-Pacific oil deposits are small and relatively shallow. Unlike the Mideast supergiants, these deposits are very rap-

Table 3.3 Oil reserves, January 1994, and crude production, 1993, by economy and region

	Reserves (January 1994)		Production (1993)		
Economy or region	(million barrels)	Share of total (%)	(thousand barrels per day)	Share of total (%)	RP ratio (years)
China	24,000	2.4	2,880	4.8	23
India	5,921	0.6	560	0.9	30
Indonesia	5,779	0.6	1,530	2.6	10
Malaysia	4,300	0.4	650	1.1	16
Australia	1,615	0.2	496	0.8	10
Brunei	1,350	0.1	156	0.3	24
Vietnam	500	0.1	126	0.2	11
Other Asia-Pacific	1,184	0.1	317	0.5	12
Asia-Pacific total	44,647	4.5	6,715	11.2	18
Middle East total	662,866	66.3	18,336	30.7	99
World total	999,131	100.0	59,752	100.0	46

Sources: *Oil & Gas Journal Data Book* (1994 edition) and EWC PREM Data File.
Note: Rounding errors occur.

Table 3.4 Crude production by producer, 1980–93, with projections to 2010

Scenario and producer	Production (thousand barrels per day)					Growth rate (%)		
	1980	1990	1993	2000	2010	1993–2000	2000–2010	1993–2010
Base case total	5,025	6,450	6,715	6,768	6,500	0.1	-0.4	-0.2
Australia	436	576	496	350	150	-4.9	-8.1	-6.8
China	2,122	2,768	2,880	3,200	3,450	1.5	0.4	1.1
India	195	665	560	650	750	2.2	1.4	1.7
Indonesia	1,663	1,462	1,530	1,050	750	-5.2	-3.3	-4.1
Malaysia	278	623	650	526	350	-0.3	-4.0	-3.6
Vietnam	0	54	126	360	450	16.2	2.3	7.8
Others	331	302	473	632	600	4.2	-0.5	1.4
High case total	–	–	–	7,700	7,500	2.0	-0.3	0.7
Low case total	–	–	–	5,700	4,500	-2.3	-2.3	-2.3

idly exhausted; some have sharp peaks in production only two or three years after start-up, followed by quick declines. A large number of important Asia-Pacific fields are already far along their depletion curves, and continuous new investment in exploration is needed merely to maintain production rates at the current level.

Scenarios of crude production by country are presented in Table 3.4 and Figure 3.3. In the base case scenario, the region's crude oil production will be nearly 6.8 mmb/d in 2000 and will decline slightly to 6.5 mmb/d in 2010. This projection reflects short term increases, followed by gradual declines, in Indonesian and Malaysian production; strong and steady increases in Burmese, Chinese, and Vietnamese production; and a much slower decline than has previously been foreseen for Australian output. The lower case scenario takes into account the possibility of significant decreases in Indonesian and Malaysian output after the exhaustion of enhanced oil recovery options and the possibility of no increases in China's or Vietnam's output. The high case scenario, on the other hand, takes into consideration higher-than-expected output levels in general and the possibilities of substantial production gains from developments such as China's Tarim Basin and from further offshore discoveries in the South China Sea.

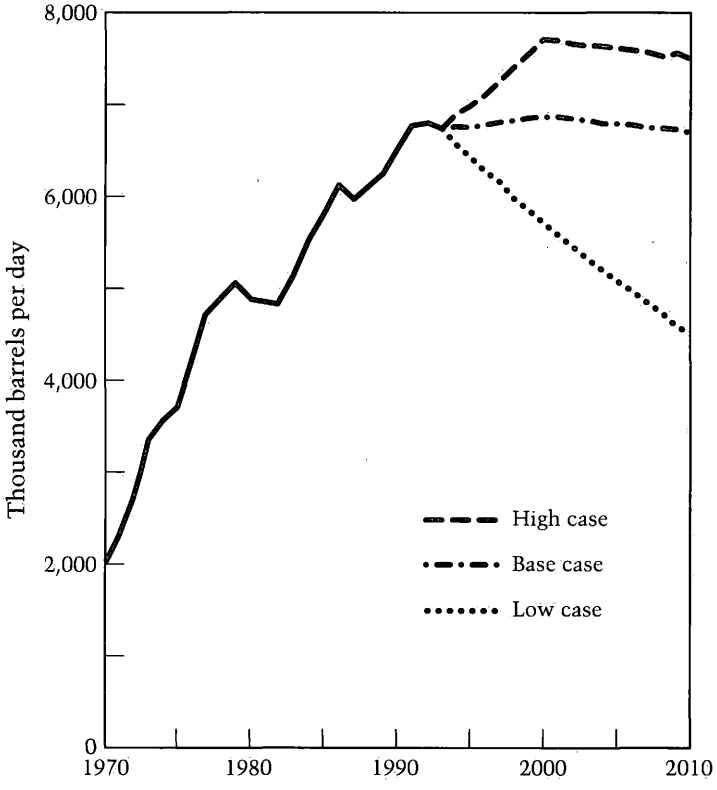


Figure 3.3 Asia-Pacific crude oil production, 1970–93, with base, low, and high case projections to 2010

Asia-Pacific crude production is unable to satisfy existing regional demand, and the gap between supply and demand will widen rapidly. The result will be a major increase in import dependence. Oil imports from outside the region will account for two-thirds of the region's consumption by 2000 and three-fourths by 2010 (see Figure 3.4). Most of these imports will come from the Middle East (see Figure 3.5), unless alternative sources of petroleum supply can be found.

Most of the crude oil currently exported by the region's own net oil exporters is traded within the region, and the amount of crude oil available from these exporters will decline because their domestic demand is rising faster than production. In 1993 a total of 6.7 mmb/d of crude was produced within the region; 4.5 mmb/d of this total was required to satisfy domestic demand in the producing countries, leaving

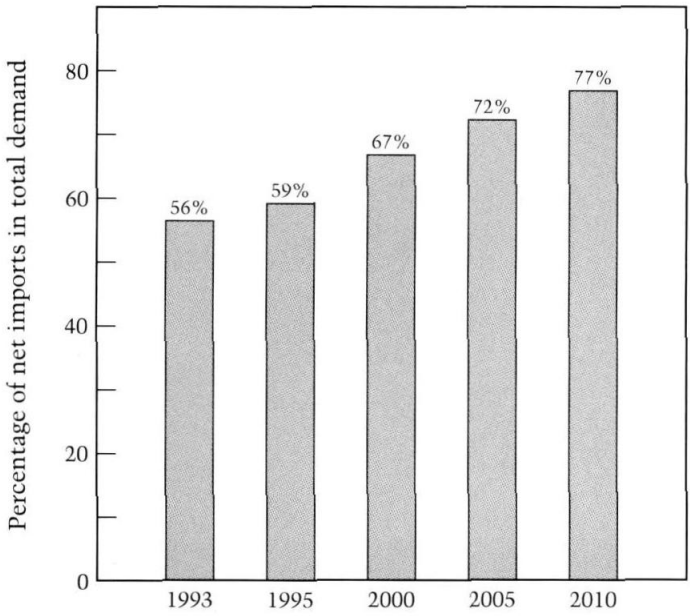


Figure 3.4 Asia-Pacific oil (crude and products) import dependence, 1993, with projections to 2010

only 2.2 mmb/d for export. About 86 percent of the exported crude was traded within the region; the remainder went mostly to the United States. By 2000, the amount of oil available from the region's net exporters is projected to fall to around 1 mmb/d. China is expected to become a net crude oil importer in 1995 or 1996, and Indonesia will follow around the turn of the century. After 2000, the region's net exporters will be Brunei, Malaysia, Papua New Guinea, and Vietnam. Vietnam at that time will be a sizable oil producer, although the amount of oil available for export will be limited because of rising domestic consumption. By 2010, all countries in the region (except Brunei and perhaps Papua New Guinea) will become net crude oil importers.

As a result of these changes, exports of low-sulfur waxy crudes will decline significantly. Among Asia-Pacific crude types, light sweet crudes will be harder to find than heavy sweet crudes. The regional slate will also depend more heavily on sour crudes from the Middle East. The change in the crude slate to more sour crude (i.e., oil with higher sulfur content)

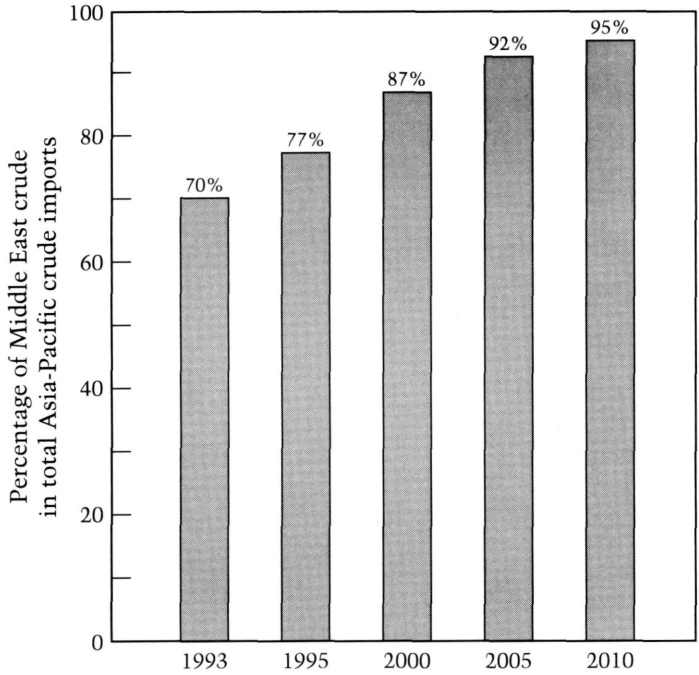


Figure 3.5 Asia-Pacific dependence on Middle East crude, 1993, with projections to 2010

Note: Asia-Pacific intraregional crude trade is included in the total. Product trade is not included.

will have a major impact on refining investments, since environmental regulations will require lower-sulfur product specifications.

The region's refining capacity in 1993 was 14.6 mmb/d. Additions of nearly 3.6 mmb/d of capacity are firmly planned or under construction, and a further 4.4 mmb/d of capacity are under serious study. Total refining capacity in the region is likely to increase to 18.9 mmb/d in 2000 and 25 mmb/d in 2010. Although additions of facilities to handle Mideast crudes and to meet the demand for lighter products have also been planned, the gasoline maximizing technologies currently under construction and planned are not expected to satisfy the rapidly growing demand for middle distillates. Therefore, despite the expansion of refining capacity, production in the region will not catch up with oil product demand, and the

region as a whole will continue to be a net product importer throughout the outlook period to 2010.

The region's net oil imports in 1993 consisted of 6.9 mmb/d of crude and 1.7 mmb/d of products. Net imports are projected at 10.5 mmb/d of crude and 2.8 mmb/d of products in 2000 and at 16.6 mmb/d of crude and 3.5 mmb/d of products in 2010. Net product imports from outside the region satisfied 8.8 percent of total oil demand in the region in 1993. This share is expected to rise to about 14.2 percent in 2000. It could be as high as 13.2 percent in 2010, even though the region's refiners will be expanding their capacity continuously.

In many countries, government subsidies are keeping diesel and kerosene prices too low. Under these conditions, refiners have been discouraged from investing in new hydrocracking units to increase yields of diesel and other middle distillates, in spite of the huge demand for these products. The consequent shortages of diesel have made large imports of diesel from outside the region unavoidable, and 36 percent of total product imports in 2000 will be diesel alone. To correct the market distortion caused by such interventions in oil prices, many countries in the region are now moving toward deregulation of the oil industry. Countries such as Malaysia, the Philippines, and Thailand have adopted domestic pricing based on Singapore postings, which reflect the international market prices. The refining industry will become liberalized as governments provide the "right" incentives for domestic refineries to optimize production. Output will then become oriented toward market opportunities, including exports, and will gradually become subject to outside competition.

NATURAL GAS

Natural gas has become the fuel of choice particularly among the region's electric power utilities, which place a premium on gas because of security of supply, minimal price volatility, and environment-friendly qualities. It is expected that gas use will expand, as additional discoveries are made, as the distribution system develops, and as a "gas utilization

culture" emerges in the region. The use of gas is relatively new in the Asia-Pacific region. As the governments and industries become familiar with established and new uses of gas, and as they prepare to make the heavy start-up investments in infrastructure and distribution, the consumption of gas is certain to increase rapidly. The outlook for the turn of the century is shown in Figure 3.6, which displays two

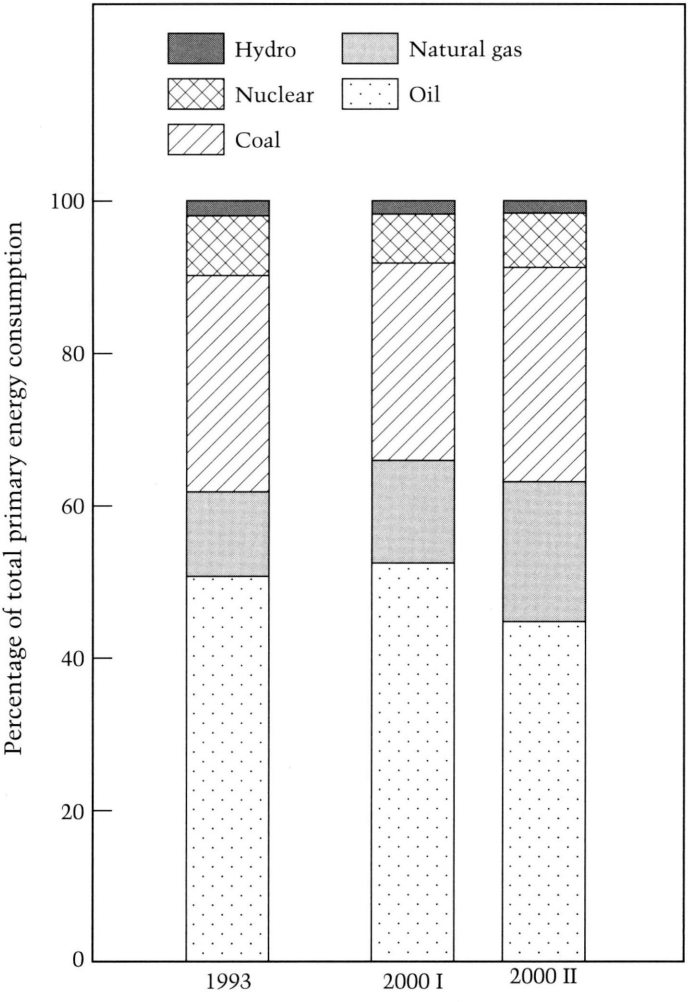


Figure 3.6 Structure of Asia-Pacific primary energy consumption, 1993, with projections to 2000

Note: The data exclude China. The oil price per barrel is assumed to be US$15 in the low case scenario (2000 I) and US$23 in the high case scenario (2000 II).

scenarios of oil prices per barrel, at a low level of $15 and a high level of $23 in real 1993 prices. The share of gas grows much faster in the high oil price scenario than in the low one. At a low oil price, many (perhaps all) new grass-roots LNG projects may not materialize, but domestic utilization of gas would still be considered a high priority. The increase will be a function of both environmental and energy security considerations.

NATURAL GAS DEMAND

Demand for natural gas in the region has increased substantially during the past two decades. In 1993 the Asia-Pacific countries consumed nearly 6.2 trillion cubic feet (tcf) of natural gas, compared with only 1.1 tcf in 1973. Japan is by far the largest consumer (accounting for 32% of total gas consumption in the region), followed by Australia (10%), India (9%), and China (9%) (see Figure 3.7).

Natural gas demand will continue to increase significantly, in almost any scenario. Figure 3.8 shows projected

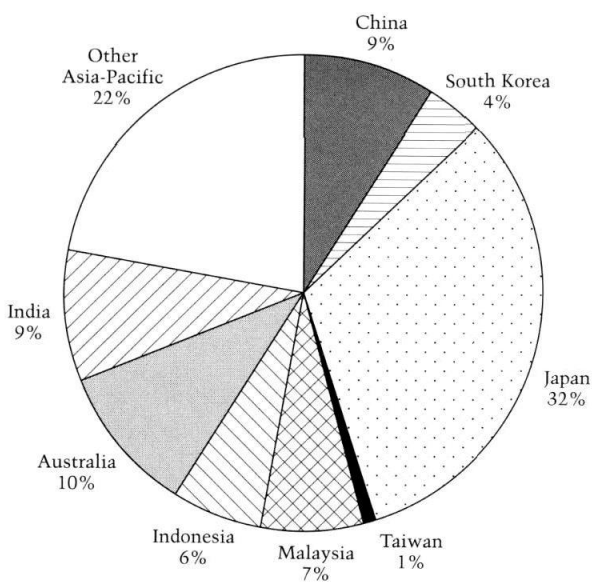


Figure 3.7 Structure of Asia-Pacific natural gas consumption, 1993

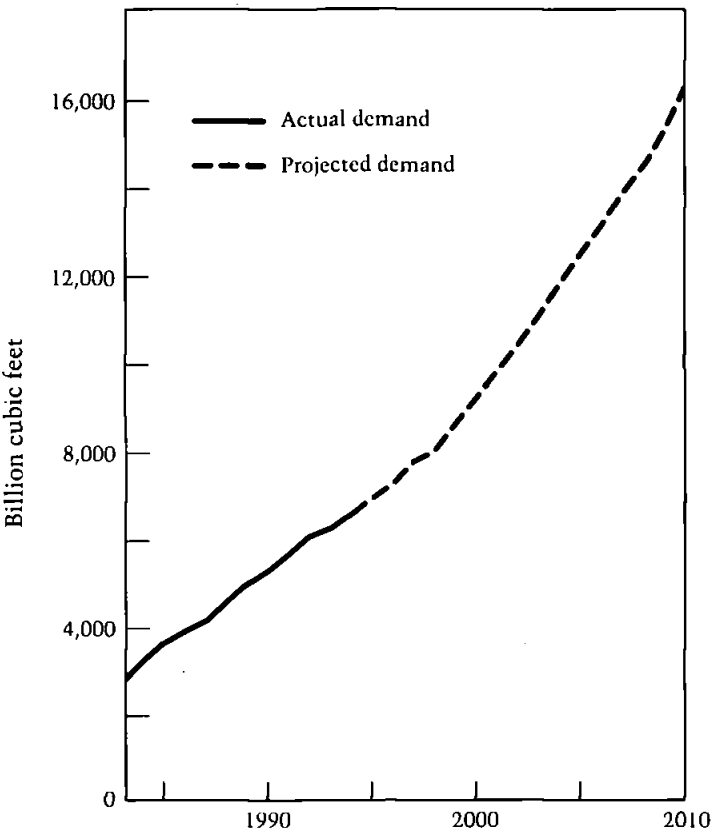


Figure 3.8 Asia-Pacific natural gas demand, 1983–93, with projections to 2010

natural gas demand to the year 2010. The base case growth rate (about 6% per year) would raise total natural gas demand in the region from 6.2 tcf in 1993 to 16.2 tcf in 2010.

NATURAL GAS SUPPLY

The Asia-Pacific countries produced 17.3 billion cubic feet per day (bcf/d) of natural gas in 1993. Indonesia alone produced nearly 5.2 bcf/d, and Australia produced 2.3 billion cf/d (see Table 3.5). About 7.1 percent of proven world reserves of natural gas are in the Asia-Pacific region. Since the rate of exploitation is still relatively low, the region has a reserves-to-production ratio of around fifty-six years. Malaysia has the

Table 3.5 Natural gas reserves and production by producer, 1993

Producer	Reserves		Production		
	Volume (trillion cubic feet)	Share of total (%)	Volume (million cubic feet per day)	Share of total (%)	R/P ratio (years)
Australia	19.6	0.39	2,321.4	1.10	23
Brunei	25.2	0.50	856.2	0.41	81
China	59.0	1.18	1,602.2	0.76	>100
India	25.4	0.51	1,511.2	0.72	46
Indonesia	64.4	1.28	5,154.2	2.45	34
Malaysia	76.7	1.53	2,006.6	0.95	>100
New Zealand	3.2	0.06	460.8	0.22	19
Pakistan	22.9	0.46	1,424.4	0.68	44
Papua New Guinea	15.0	0.30	7.9	0.00	>100
Thailand	5.7	0.11	860.8	0.41	18
Vietnam	3.7	0.07	67.4	0.03	>100
Other Asia-Pacific	33.7	0.67	977.8	0.46	94
Asia-Pacific total	354.5	7.07	17,251.0	8.19	56
Middle East total	1,581.0	31.52	10,858.9	5.16	>100
World total	5,016.2	100.00	210,635.1	100.00	65

Source: *Oil & Gas Journal.*
Note: Rounding errors occur.

largest gas reserves in the region (about 76.7 tcf), although Indonesia is the biggest producer and currently produces more than twice as much as Malaysia. The countries in the region that possess gas resources are far more numerous than those that possess oil reserves, and the outlook is generally brighter for gas than for oil. The region is still in the early stages of finding gas and learning the scope of its uses. It is also very likely that any significant new gas discoveries will be used domestically, and there will not be much available for export.

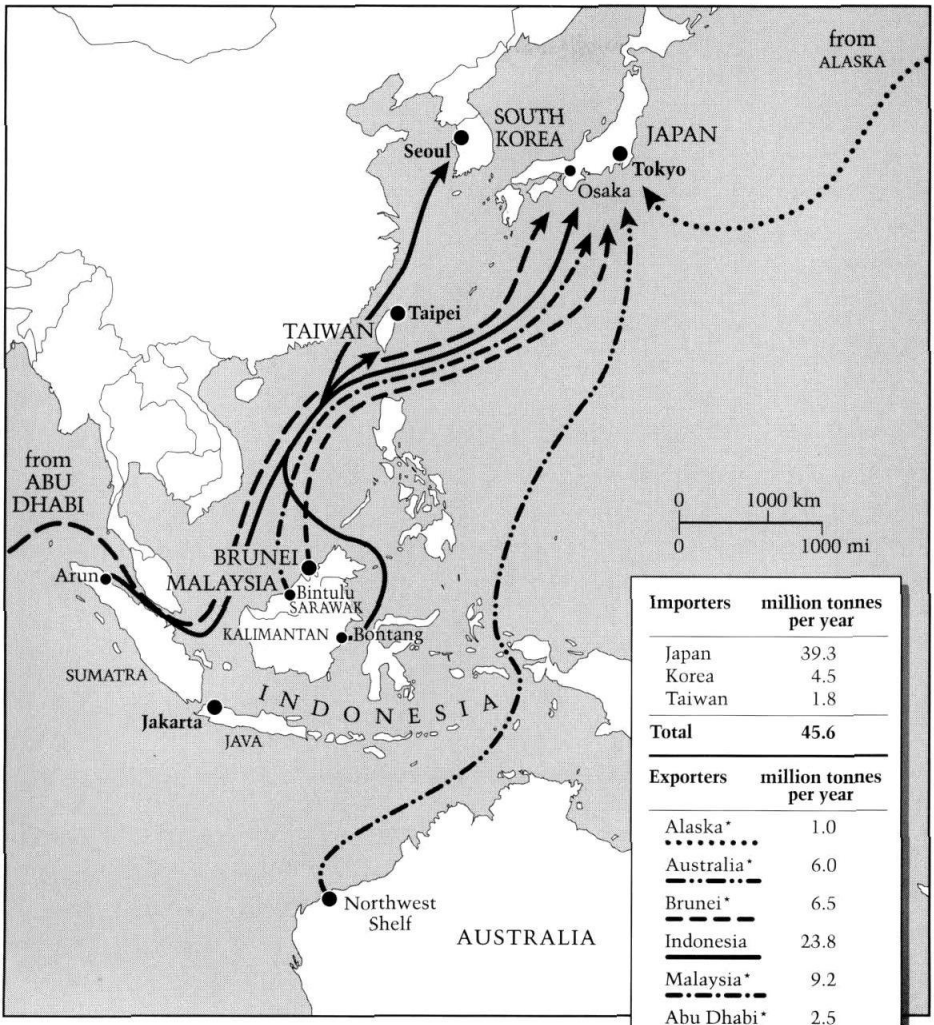
Although new gas reserves have been discovered in the region, many of them tend to be in areas where the cost of development will be significantly higher than those already developed. Consequently, rampant demand and the high cost of developing gas reserves in the region have led buyers to look farther afield—once again toward the relatively lower-cost reserves of the Middle East. Despite the high transportation costs involved, the countries of the Middle East, with

their abundant reserves of gas, seem to be the likely future sources of gas supply for the growing markets of the Asia-Pacific region.

LNG DEMAND AND SUPPLY OUTLOOK

The environmental benefits of burning natural gas, rather than the other less clean-burning fossil fuels, have been and continue to be the most powerful argument in favor of natural gas use, particularly in the developed Asia-Pacific countries, where environmental regulations are becoming stricter every year. Many countries in the region are beginning to use their own gas reserves to fuel the power sector and to supply domestic industry. Some of the region's main consumers of natural gas, however, have hardly any domestic reserves and are therefore involved in an LNG trade of vast proportions. Because the suppliers are separated from the principal consuming markets by thousands of miles of water, pipeline options are uneconomical, and therefore gas has to be transported in the form of LNG at present. As indicated below, however, domestic pipeline networks are under construction in some countries and are expected to become linked eventually into an international network.

The Asia-Pacific region is involved in more than 80 percent of total world trade in LNG and accounts for more than 75 percent of world LNG consumption. The six suppliers that export to countries within the region (see Figures 3.9 and 3.10) produced a total of 49 million tonnes (mmt) of LNG in 1993. Most of this total was produced and consumed within the region itself. The region's largest LNG producer is Indonesia (23.8 mmt in 1993), and the other producers are Malaysia (9.2 mmt), Brunei (6.5 mmt), and Australia 6.0 mmt). Two extraregional suppliers—Abu Dhabi and Alaska—produce exclusively for the Japanese market. Since total LNG consumption in the region was 45.6 mmt in 1993, the excess supply produced within the region that year was sold to European buyers. The region's LNG consumers are Japan, South Korea, and Taiwan. In 1993 Japan accounted for about 65 per-



Importers	million tonnes per year
Japan	39.3
Korea	4.5
Taiwan	1.8
Total	**45.6**

Exporters	million tonnes per year
Alaska*	1.0
Australia*	6.0
Brunei*	6.5
Indonesia	23.8
Malaysia*	9.2
Abu Dhabi*	2.5
Total	**49.0**

*to Japan only

Figure 3.9 Asia-Pacific LNG trade, 1993

cent of world LNG consumption and 86 percent of consumption within the Asia-Pacific region.

The fast-growing electricity demand, the problems associated with nuclear power, and environmental problems related to coal fired power plants have resulted in big increases in LNG demand in East Asia. Japan will continue to be the single most important LNG consumer in the world. Its LNG demand is expected to rise from 39.3 mmt in 1993 to 54 mmt

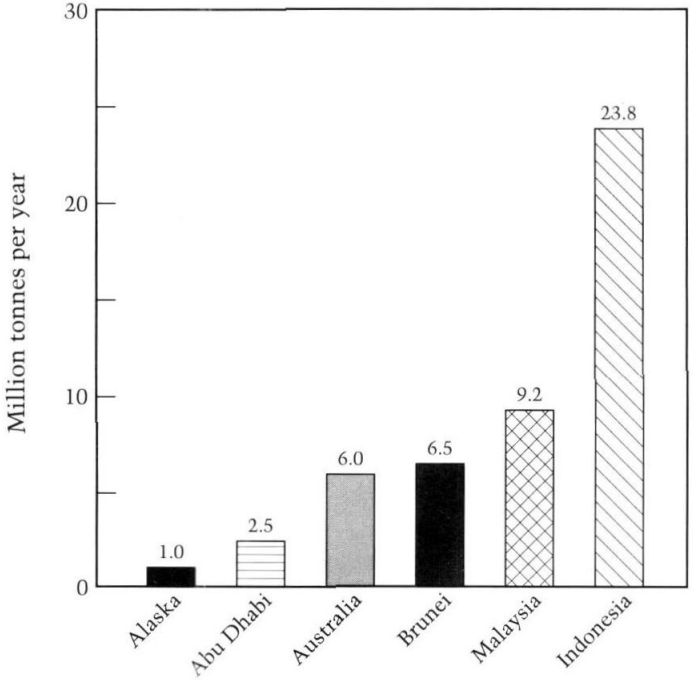


Figure 3.10 LNG exports by supplier, 1993

in 2000 and 70 mmt in 2010. Although much of this increase is slated for the power sector, the Japanese government hopes to increase the use of natural gas in the industrial and residential sectors also. In South Korea, LNG demand was 4.5 mmt in 1993 and is expected to reach 10 mmt in 2000. Demand in Taiwan will rise from 1.8 mmt in 1993 to about 7 mmt in 2000, as gas-based power generation capacity jumps from 1,030 MW in 1993 to 6,045 MW in 2000. By the year 2010, the combined South Korean and Taiwanese demand is expected to reach 30 mmt. Potential LNG consumers (China, India, and Thailand) will push the region's total LNG demand in 2010 above 100 mmt, which will be more than double the present level (see Table 3.6).

Many projects are currently being debated in East Asia, for a potential 90 mmt per year of additional LNG supplies. The only firm projects coming on stream by 2000 are the two Qatari projects: Qatargas and Ras Lafflan (Rasgas). Between 2000 and 2005, the only grass-roots projects that will

Table 3.6 LNG demand, 1993, with projections to 2010 (million tonnes per year)

Consumer	1993	2000	2005	2010
Japan	39.3	54.0	60.0	70.0
Taiwan	1.8	7.0	12.0	14.0
Korea	4.5	10.0	13.0	16.0
China	0.0	0.0	2.0–6.0	2.0–6.0
Thailand	0.0	0.0	2.0–4.0	2.0–4.0
India	0.0	0.0	2.0–4.0	2.0–4.0
Total	45.6	71.0	91.0–99.0	106.0–114.0

supply the region are in Oman and possibly Malaysia. (Many projects entail expansions of existing facilities, and it is not yet clear whether Malaysia's MLNG-III will be a grass-roots project or an extension of the existing Bintulu plant in Sarawak.) Beyond 2005, most projects will be grass-roots facilities, although their future is obscured by technical, financial, and political factors. The future grass-roots projects for the supply of the East Asian markets are listed in Table 3.7.

The expansion of capacity by existing suppliers will boost supplies available in 2000 by more than 16 mmt (Figure 3.11). But given high demand growth in Japan, South

Table 3.7 Outlook for new LNG projects, 2000–2010

Producer and project	Volume (million tonnes per year)
Firm by 2000	
Qatar: Qatargas	6.0
Qatar: Ras Lafflan	2.5–5.0
Likely by 2005	
Oman	5.0
Russia: Sakhalin, Russian Far East	2.0–4.0
Malaysia: MLNG-III, Sarawak	4.0
Likely by 2010	
Qatar: Ras Lafflan II	5.0
Australia: Gorgon/East Spar (Western Mining)	2.0–4.0
Possible by 2010	
Yemen	5.0
United States: Prudhoe Bay, Alaska	14.0
Indonesia: Natuna	12.0
Papua New Guinea: Pandora	4.0

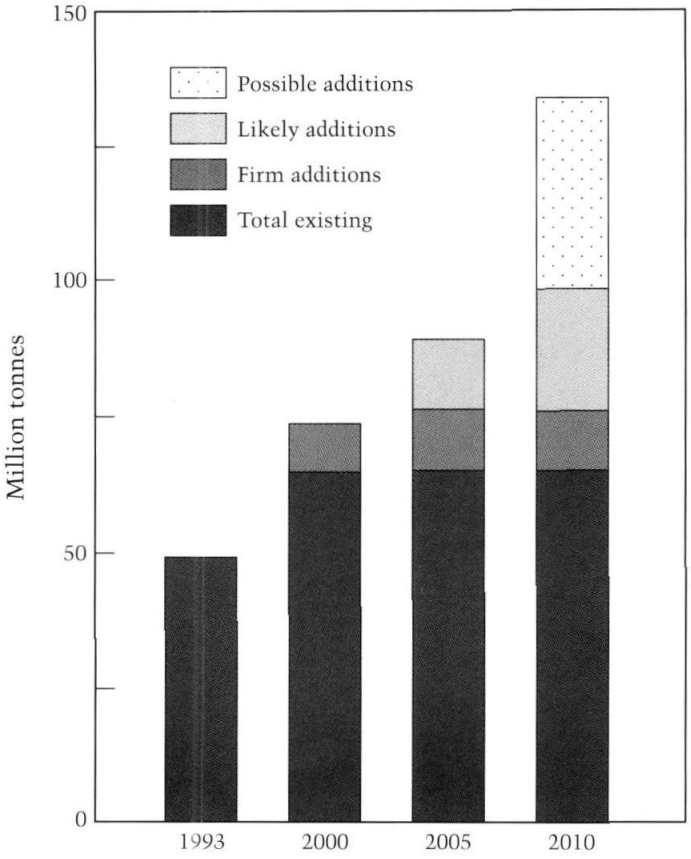


Figure 3.11 Asia-Pacific LNG supply, 1993, with projections to 2010

Korea, and Taiwan, and the entry into the LNG market of potential new buyers such as China, India, and Thailand, new projects will become a necessity by the end of next decade, if LNG demand is to be satisfied (see Table 3.6). Assuming total regional demand for LNG in 2010 is in the range of 106–114 mmt, more than 34 mmt of production will have to come from grass-roots projects. Given the certainty that at least 6.5 mmt of LNG from the Qatargas and Rasgas projects will be on the market by 2000, and the likelihood of some new supplies (Oman and MLNG-III) coming on stream by 2005, the demand in the major LNG consuming countries appears secure until the middle of the next decade. However, huge

efforts will be needed to jump start the rest of the projects, which are currently stalled because of poor economics.

Aside from the projects already mentioned, a half-dozen or more other grass-roots projects have been proposed to provide supplies to the region (see Table 3.7). All of them have been delayed, however, because of rising construction costs and low oil prices, which make them either financially nonviable or economically marginal.

The generally low oil prices have made the financing of future grass-roots projects very troublesome. During the past year, LNG prices declined substantially, reflecting the weak crude oil prices to which they are linked. As oil prices improve, however, LNG prices will begin to pick up. Higher prices for LNG are vital for the future of the grass-roots projects, since the new reserves are in remote areas far from consumption centers and are difficult and costly to develop. For projects such as those of Qatargas and Rasgas, lower development costs provide a comparative advantage, although transportation costs will be high. For Oman, the onshore location of the reserves ensures relatively fast and cheap development. Therefore, these projects could become viable at lower price levels than those in Sakhalin (Russian Far East), Alaska, and Indonesia's Natuna, where the cost of development would be substantially higher.

The industry is facing a dilemma: there is a very large potential demand for LNG in East Asia, but the supply cannot be brought forth under the current market conditions. As a result, there is a desperate need to improve the pricing mechanism for LNG. A higher LNG price could be achieved in four ways:

1. Assess a premium over the oil prices formula by deeming a crude price (i.e., agreeing on a fixed price that is unaffected by market fluctuations)
2. Assess floor and ceiling prices of LNG
3. Assess a price based on alternative fuels, such as coal
4. Assess a price based on gas-to-gas competition or LNG spot prices.

Option 4 does not seem viable in the Asia-Pacific region.[1] Option 3 can result in an LNG price of at least $5 per million Btu (mmBtu), given the efficiency of using gas for power generation and the smaller size of plants. The Qatargas project uses option 2: a minimum is set for the price of Qatar's LNG, and an inflation index, as a fixed price escalator, is factored into the price formula. This method protects the investors from oil price declines, while also guaranteeing a reasonable margin in the operating costs of the project. At the same time, a ceiling price is considered necessary by the buyers, to provide guarantees against a sudden excessive rise in the price of crude oil. The floor price will vary from project to project. Ultimately, however, the practical way to build a price formula is to assess a premium by deeming a crude price (option 1).

Higher LNG prices are unavoidable if the potential demand in the Asia-Pacific region is to be met. Otherwise, natural gas may lose out to other fuels—to oil in particular. Given the fact that other fossil fuels can easily be substituted for LNG, the critical factor is that the LNG demand will materialize only if the supply is established. Should crude prices remain at present levels or fall any further, it is unlikely that the buyers will find it possible to procure LNG, and therefore they may seek alternative fuels.

Table 3.8 and Figure 3.12 illustrate four different scenarios of the LNG balance in the region. The first scenario assumes that only the existing projects are completed. In this case there will be shortages as early as the year 2000. However, if the firm projects are completed on time (scenario 2), no shortages are expected until 2005. The subsequent balance, however, will depend on the number of proposed projects that do materialize. The supply from at least a few of the proposed projects must become available if the grow-

1. At least it does not seem viable in the foreseeable future. That type of pricing mechanism could become viable only when more sellers become involved and the region's pipeline networks are in place. In addition, the sizes of the natural gas megaprojects and the huge investments involved in them make it impossible for such a mechanism to function properly at the present time.

Table 3.8 Asia-Pacific LNG supply-demand balance, 2000–2010 (million tonnes per year)

Type of project	2000	2005	2010
Existing projects	-5.7	-19.3	-34.3
Existing and firm projects	2.8	-8.3	-23.3
Existing, firm, and likely projects	2.8	4.7	-1.3
Balance of all projects[a]	2.8	-6.3	23.7

a. Including possible and potential projects and potential new buyers.

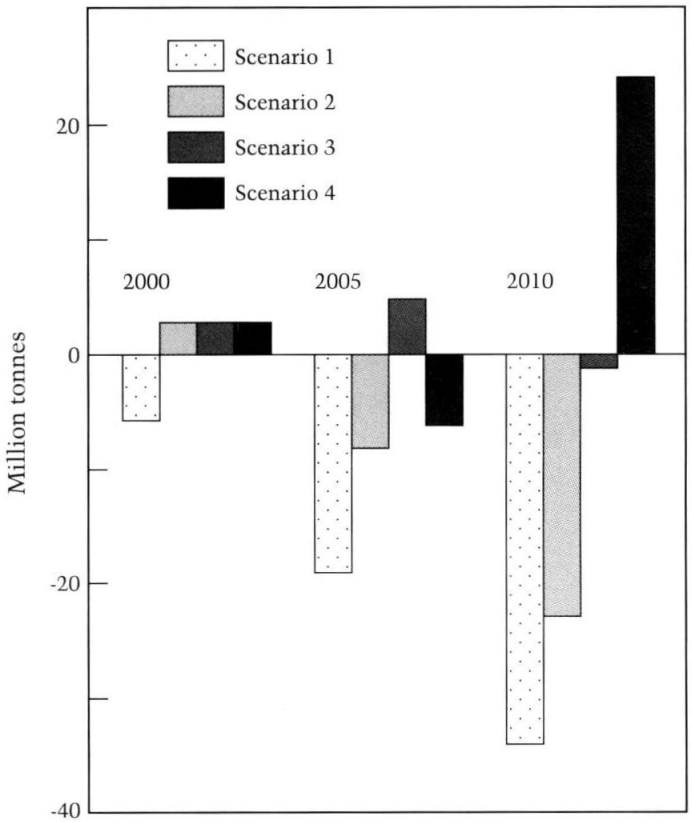


Figure 3.12 Asia-Pacific LNG supply-demand balance, 2000, 2005, and 2010

ing demand around the end of the next decade is to be met. The completion of the likely projects can alleviate the otherwise inevitable shortages and improve the balance considerably (scenario 3). On the other hand, new buyers will enter

the LNG scene, possibly as early as 2005, and will add to the strain on supply availability. Scenario 4 is based on the materialization of all the proposed projects, and it also takes into consideration the addition of potential new buyers. The result of this case would be a large LNG surplus in the region—which is an unlikely outcome, given the huge investments involved.

An international gas pipeline network has been proposed in connection with some natural gas projects. The much discussed system that would link the member countries of the Association of Southeast Asian Nations (Brunei, Indonesia, Malaysia, the Philippines, Singapore, and Thailand) still seems a long way off, given the fact that so many national pipeline systems have to be built before this trans-ASEAN gas network comes into being. At present, there is only one international pipeline in the region, linking Malaysia and Singapore. Another important project already under construction and due to be completed in 1995 is the submarine trunkline linking a Chinese offshore field, southeast of Hainan Island, to a receiving station in Hong Kong. The cost of this 700 kilometer pipeline is estimated at $1.2 billion, and the first gas deliveries are expected in 1996. The most elaborate plan for the future is a pan-Asian gas network, which would start in the Russian Far East and connect to the proposed Korean and Japanese domestic pipeline systems, with a bypass line connecting from Alaska. The main line would continue south, along the east coast of China, link to the proposed trans-ASEAN network, and extend to the west coast of Australia. The cost of this project is estimated at $25 billion. Among the serious obstacles to the progress of such projects are the high capital expenditure required and the impact of such a system on the region's LNG countries, which currently rely on revenues from the LNG trade. Therefore, these projects are deemed to be lower in the scale of priorities and economics than the LNG projects, particularly since LNG is priced in relation to crude oil, whereas piped gas is priced in relation to high-sulfur fuel oil.

It is certain that gas use will continue to grow in this

part of the world, and the power sector will be the major impetus for this growth. Under any scenario, therefore, Japan, South Korea, and Taiwan will remain dependent on natural gas imports, either in the form of LNG or through pipelines. Given the very slow progress of all the pipeline projects in the region, and the cost of all the related infrastructure, LNG is the only option for transporting natural gas to these "isolated consumers" for at least the next decade.

COAL

Dependence on coal to satisfy primary energy needs is higher in the Asia-Pacific region than in any other region of the world. About 46 percent of the region's commercial energy requirement is filled by coal, compared with 21 percent for the remainder of the world.[2] The dominant factor in the high percentage of coal use in the region is China, the world's leading producer and consumer of coal.

Coal is by far the region's most abundant fossil fuel resource, and it will remain the dominant primary fuel consumed during the outlook period to 2010. The rate of growth of coal consumption in the region is dependent not only on economic growth rates in the region but also on coal's ability to meet increasingly stringent environmental regulations, particularly those associated with coal use in generating electricity. Coal is a major contributor to air pollution, and it is facing challenges from cleaner alternatives: natural gas, nuclear energy, and hydropower.

Coal is broadly classified as either thermal or metallurgical coal. Thermal coal dominates the market and is expected to account for more than 90 percent of the consumption growth during the outlook period. Thermal coal is used in electricity generation, industrial boilers, and cement manufacturing; it is also used in households for cooking and heating. Metallurgical coal is used primarily for making steel. Thermal coal typically sells for about $35 per tonne delivered to coastal power plants, whereas metallurgical coal sells

2. Except where noted, lignite is excluded from the coal statistics in this study.

for $45 per tonne or more, depending on quality factors. In recent years, technological advances have allowed partial substitution of lower quality coals, both metallurgical and thermal, as pulverized coal injection in steel making.

Most western coal companies have historically viewed the Asia-Pacific region as an export market for metallurgical coal. The exception to this generalization is Australia, where large investments have been made in low-cost development of both metallurgical and thermal coals. In recent years, corporate strategies have shifted, and western corporations are searching for investment opportunities to develop coal mines elsewhere in the region, particularly in China and Indonesia. Australia is expected to continue to lead the region in attracting foreign investment in coal, and foreign investors are developing large coal mines in Indonesia. Foreign investors are also evaluating potential coal mine developments in China. In the early 1980s, they viewed China as a source of coal for the export market. Today, however, companies view coal developments in China in terms of the domestic Chinese market. The possibility of linking coal mine developments with the construction of large coal fired power plants is receiving considerable attention. However, the current caution toward investment in coal mines in China is due to uncertainties about investment terms, long term coal prices in the domestic market, and currency convertibility.

COAL PRODUCTION, CONSUMPTION, AND TRADE

A number of factors have to be considered when preparing projections of production, consumption, and trade of coal in Asia. The three most important factors are reviews of government plans for coal use in each economy, projections of economic and electricity growth rates in each economy, and assessments of the competitive position of coal in relation to alternative energy sources. (The last-named factor assumes that tighter environmental standards will apply before 2000.) The projections are considered to be accurate only within ranges of plus or minus 5–10 percent in 2000 and plus or

Table 3.9 Coal production, 1993, with projections to 2010 (million tonnes)

Producer	1993	1995	2000	2010	Change 1993–2010
China	1,141	1,244	1,500	2,000	859
India	249	278	352	568	319
Australia	185	196	225	305	120
North Korea	34	37	45	50	16
Indonesia	28	39	68	105	77
South Korea	9	8	7	4	-5
Japan	7	6	3	1	-6
Vietnam	5	6	9	18	13
Philippines	2	2	3	4	2
Other Asia-Pacific	6	7	9	13	7
Total	1,666	1,825	2,221	3,068	1,402

Note: The data exclude production of lignite. Rounding errors occur.

minus 10–20 percent in 2010. In some cases, such as the Chinese and Indonesian coal exports and the Vietnamese coal trade, the estimates for 2010 are even less certain and may vary by substantially more than 20 percent.

Coal production in the important coal producing economies of the region during the outlook period is shown in Table 3.9.[3] Total regional production is expected to grow at an average of 3.7 percent per year, from 1.67 billion tonnes in 1993 to 2.22 billion tonnes in 2000 and 3.07 billion tonnes in 2010. Australia, China, and India are expected to account for 94 percent of the region's growth in coal production.

Total consumption is expected to increase by an average of 3.7 percent per year, from about 1.7 billion tonnes in 1993 to 2.3 billion tonnes in 2000 and 3.1 billion tonnes in 2010 (see Table 3.10). China and India will continue to account for more than 80 percent of the region's coal consumption during this period.

The region has four net coal exporters: Australia, China, Indonesia, and Vietnam. Among these four countries, net ex-

3. Estimates for North Korea are speculative but are included because the country is an important coal (anthracite) producer and consumer. Expected changes in the North Korean economy during the outlook period may have an important impact on the North Korean coal trade.

Table 3.10 Coal consumption, 1993, with projections to 2010 (million tonnes)

Consumer	1993[a]	1995	2000	2010	Change 1993–2010
China	1,123	1,224	1,478	1,975	852
India	257	288	365	590	333
Japan	118	124	138	150	32
Australia	53	56	62	75	22
South Korea	40	44	54	77	37
North Korea	35	39	48	58	23
Taiwan	25	28	35	53	28
Hong Kong	12	12	13	15	3
Indonesia	10	17	34	68	58
Philippines	3	6	14	21	18
Vietnam	3	4	5	11	8
Thailand	2	4	8	15	13
Other Asia-Pacific	9	11	16	23	14
Total	1,690	1,857	2,270	3,131	1,441

Note: Consumption includes adjustments to coal stocks but does not include lignite.
a. Data for 1993 are preliminary.

Table 3.11 Coal trade, 1993, with projections to 2010 (million tonnes)

Trade status	1993	1995	2000	2010	Change 1993–2010
Net exporters					
Australia	132	143	163	230	98
China	18	19	22	25	7
Indonesia	18	19	34	37	19
Vietnam	2	2	4	7	5
Total net exports	170	184	223	299	129
Net importers					
Japan	111	122	135	149	38
South Korea	31	34	47	73	42
Taiwan	25	28	35	53	28
Hong Kong	12	13	13	15	3
India	8	9	13	22	14
Thailand	2	2	8	15	13
North Korea	1	1	3	8	7
Philippines	1	1	11	17	16
Others	3	3	7	10	7
Total net imports	194	214	272	362	168

Note: The data exclude trade in lignite. Rounding errors occur.

ports are expected to increase at an average rate of 3.4 percent per year, from 170 million tonnes in 1993 to 223 million tonnes in 2000 and nearly 300 million tonnes in 2010 (see Table 3.11). Australia's share of the net export trade is expected to decrease from 78 percent in 1993 to 73 percent in 2000, but it will then gradually increase to 77 percent by 2010. China and Indonesia exported approximately the same net amounts of coal in 1993, but Indonesia's net exports will pull decisively ahead of China's before the end of the century. In terms of gross exports, however, China will become the region's second largest supplier. In 2010 it will export 45 million tonnes, but its imports of 20 million tonnes will result in a net export balance of 25 million tonnes (compared with 37 million tonnes for Indonesia).

The region as a whole is a net importer, and its net imports are expected to increase on average by about 10 million tonnes per year, from 194 million tonnes in 1993 to 362 million tonnes in 2010 (see Table 3.11). Eighty-six percent of all net imports in 1993 went to the three leading importers: Japan, South Korea, and Taiwan. Their share of the total is expected to decrease to about 76 percent in 2010, as imports increase in countries such as India, the Philippines, and Thailand.

The region will continue to be a net coal importer throughout the outlook period (see Figure 3.13). In comparison with total consumption, however, the region's net imports will remain relatively small, because of the region's large coal resource base and active investment in the coal sector.

ROLE OF CLEAN COAL TECHNOLOGIES

A critical factor in any projection of the region's coal use during the outlook period is the ability of coal to meet increasingly tighter environmental standards and still remain competitive with alternative energy options. There are numerous technologies in use and under development that are broadly defined as clean coal technologies. The definition

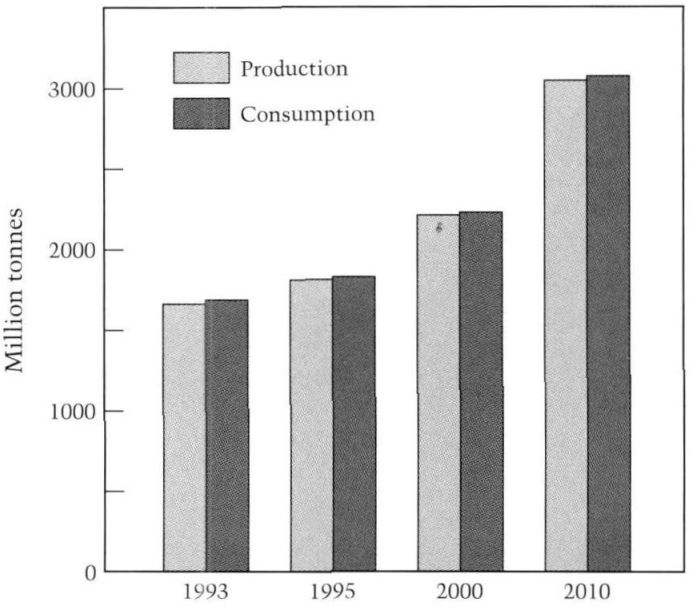


Figure 3.13 Asia-Pacific coal balance, 1993, with projections to 2010

applied in this study is the one used by the Experts Group on Clean Coal Technologies of the Asia-Pacific Economic Cooperation (APEC) forum. Clean coal technologies are technologies designed to improve the efficiency of coal use or to reduce damage to the environment or both. There is a full range of technologies for application at all stages, from coal preparation through coal utilization.

The most important environmental concerns of the majority of Asia-Pacific governments are the emissions of particulates and sulfur oxides (SO_x) associated with coal burning. China is responsible for about two-thirds of the region's SO_x emissions and consequently should be the focus of any serious international effort to reduce environmental pollution in the region. With respect to SO_x emissions, the situation in the region is complex, and a range of options has to be considered. In contrast to North America, which burns a large quantity of coal with sulfur contents higher than 1.0 percent, most coal consumed in the Asia-Pacific region contains less than 1.0 percent sulfur. The region appears to have extensive resources of very low sulfur coal (maximum 0.5%)

that can be shipped to coastal coal consumers at competitive prices.

Reducing particulate emissions from coal burning is inexpensive in large scale power plants, and the cost of meeting high standards of particulate emissions controls will not significantly reduce coal's competitive position. Clean coal technologies add about $0.01 per kilowatt hour (kWh) to the price of electricity, which typically sells for $0.05–0.08 per kWh in Asia. Notable exceptions are China and India, where average electricity prices are about $0.03 per kWh, and Japan, where prices exceed $0.11 per kWh plus a very heavy tax. The more expensive clean coal technologies, which recover more than 90 percent of SO_x emissions, add 15–30 percent to the capital cost of power plants in Asia. Considerable effort is under way, however, to develop less expensive technologies that can recover 50–80 percent of the SO_x. Such lower-cost technologies could have a much wider application in the lower-income economies than they could in the more advanced economies of the region.

Japan is the only Asian country that has universally adopted clean coal technologies. Hong Kong, South Korea, Taiwan, and Thailand are the most promising markets for adoption of such technologies by the end of the century. In contrast, Australia, China, India, Indonesia, and the Philippines are likely to depend primarily on low sulfur coal to diminish their environmental problems for at least another decade. China is expected to adopt clean coal technologies only on a selective basis; even so, it will probably be the region's first or second largest user of these technologies by 2010.

PRINCIPAL COAL PRODUCING AND CONSUMING ECONOMIES

Australia

Australia has large, high quality coal reserves within 300 kilometers of deep-water ports along its east coast. For mining projects, Australia's investment environment is among the best in the world. More than three decades of active invest-

ments in large coal mine developments and infrastructure have made Australia the world's largest coal exporter. Australia is expected to account for 70–80 percent of net exports in the region during the outlook period up to 2010.

China

China is the world's largest coal producer and consumer, and it will maintain this position throughout the outlook period. China's estimates of its coal reserves are about 1,000 billion tonnes. If western definitions are applied, however, its reserves are probably a much smaller, but impressive, 200–300 billion tonnes. The northern half of China has the largest potential—generally better geologic conditions, better coal qualities, and lower sulfur coals. The largest expansions in coal production during the outlook period will be in the inland provinces of Shanxi and Shaanxi, and the next largest will be in Inner Mongolia (see Figure 3.14). The most rapid growth in electricity demand, on the other hand, is in the coastal areas—particularly the southeast, which has limited

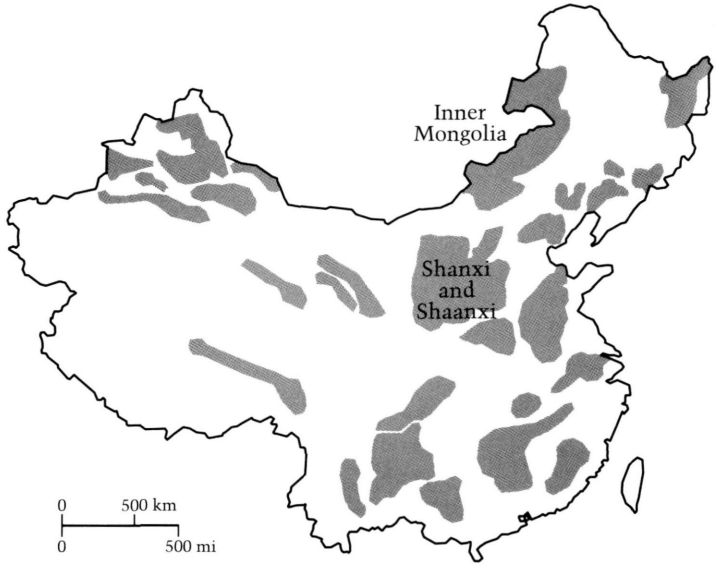


Figure 3.14 Coal fields in China

coal reserves, generally less favorable mining conditions, and coal with high sulfur contents.

Foreign investment in China's coal sector has been modest, in comparison with foreign investment in Australia and Indonesia, but interest in China has accelerated among investors during the past two or three years. A number of large, joint venture coal mine developments are likely during the second half of the 1990s. For the southeast coastal provinces, which are energy deficient and have high rates of economic growth, a rapid rise in imports is likely during the outlook period. Despite the major uncertainties about the level of foreign investment and the amount of coal trade, no major coal company can afford to ignore either China's potential impact on the region's coal trade or China as a long term investment target.

Hong Kong, South Korea, and Taiwan

Hong Kong and Taiwan are dependent on coal imports for essentially all coal requirements. South Korea's high cost anthracite coal industry is in rapid decline, and all future growth in coal consumption will come from imports. South Korea and Taiwan together will be importing an additional 70 million tonnes in 2010. Most of this increase will be thermal coal for use in coal fired power plants. In comparison, the increase in Hong Kong will be relatively small. Hong Kong's coal imports grew rapidly in the 1980s and reached 12 million tonnes in 1993, reflecting the switch from oil to coal for power generation. During the outlook period, however, most of the growth of Hong Kong's electricity generation will be supported by Hong Kong's jointly owned nuclear plant in China and by pipeline imports of natural gas.

India

India is the region's second largest producer and consumer of coal, and the growth of its coal consumption during the outlook period is expected to be the region's second largest. Domestic coal reserves are large, but tend to be high in ash content. The export potential of Indian coal is constrained by a

combination of low quality coals, inadequate investment in modern mines, and poor transport systems. In the long term, India could become a substantial importer of coal. The country's future coal trade and the pace of its coal sector development are heavily dependent on government policies.

Indonesia

Indonesia has about 36 billion tonnes of potentially mineable coal, and about 5 billion tonnes (14 percent of the potential total) are fully proven. Two-thirds of the coal resources are in Sumatra, the historical center of coal mining, and one-third are in Kalimantan. The lowest-cost developments are in Kalimantan and are being developed mostly by foreign companies. Some of these coal reserves can be mined at very low cost. They can readily compete in Asia-Pacific markets, and Indonesian exports are increasingly finding markets throughout the Pacific rim economies. Lower coal prices, together with the international trend toward tighter environmental restrictions on sulfur emissions, are improving the competitive position of Indonesian coal in international markets, since Indonesia has substantial reserves of environmentally friendly coal: that is, coal with very low sulfur and ash contents.

The growth of Indonesian coal exports is expected to slow after 2000. Indonesian government policies to promote exports and increase domestic consumption have been the most important determinant of the growth of the Indonesian coal industry during the 1990s. After the turn of the century, however, the domestic market and international environmental trends will have a more pronounced impact on Indonesian exports. The domestic market will continue to absorb an increasing share of the supply. Also, the proportion of high quality coals in total supply will decline, as less competitive deposits are developed. The early successes in Indonesian coal exports have been built on higher quality Indonesian coals, but future supplies will include the more typical, lower quality coals that constitute most of the resource base.

Japan

Japan is the largest coal importer in the world and is expected to retain this position throughout the outlook period. Imports are expected to grow from 111 million tonnes in 1993 to 135 million tonnes in 2000 and 149 million tonnes in 2010. Slightly more than half of current imports are metallurgical coal. Since imports of metallurgical coal are expected to remain almost constant for the rest of this decade, the share of thermal coal in total consumption will therefore rise. There is considerable uncertainty surrounding coal projections beyond 2000, however, because of changes under way in the structure of the Japanese economy, slow economic growth rates, and government policies to reduce CO_2 emissions.

Thailand

Since the 1970s, Thailand has been developing domestic lignite deposits, most of which are in the northern region of the country. The lignite deposits have a high sulfur content, and there are insufficient economic reserves to meet projected demand growth beyond the 1990s. The state power utility is therefore planning to import coal for electricity generation. Long term projections of coal imports are speculative, however, because of local resistance to siting power plants along the seacoast and discoveries of natural gas that could be used in place of coal.

Vietnam

Vietnam has substantial coal, oil, gas, and hydro resources. The potential for coal use in the domestic market has been dampened by a combination of recent large hydro developments and promising natural gas discoveries. The potential for coal exports has been limited in the past, because of the variable quality of the coal (anthracite), limited markets for anthracite, and infrastructure that is inadequate to handle large volumes of coal. Most of the 1–2 billion tonnes of anthracite reserves are in north Vietnam. Substantial reserves are within 30 kilometers of the coast, and the potential ex-

ists for a relatively low cost project. A slightly optimistic projection of coal production by 2010 is 15–20 million tonnes per year.

Regional Trends

Throughout the outlook period, the Asia-Pacific region is expected to continue to lead the world in the growth of coal production and consumption. Since most Asian economies have limited economic options for a shift away from coal, the region will account for 60–70 percent of world growth in coal consumption during this period.

The main uncertainty surrounding these projections is the degree to which growing environmental constraints will restrain the growth of coal consumption. Given the widespread availability of low sulfur coal in the region, and the timely introduction of appropriate clean coal technologies, coal is expected to maintain a competitive role in most Asia-Pacific economies.

The price of internationally traded coal has moved downward for more than a decade. On the basis of cost per unit of energy, coal is the lowest-cost internationally traded fossil fuel. Given the region's large coal resource base and the continued active investments for developing the region's reserves, no long term real price increases are likely for coal. During the next two years, however, there is a moderate probability of higher coal prices, as existing spare capacity in the electric power sector becomes more fully utilized.

Australia's long term position as the dominant coal exporter is not seriously threatened by the region's new coal exporters: China and Indonesia. China will continue to be the largest coal producer and consumer in the world, although the level of China's international trade is speculative.

ELECTRICITY

Electricity generation in the Asia-Pacific region is expected to increase at average annual rates of 6.5 percent from 1993 to 2000 and 5.3 percent from 2000 to 2010. These rates are much higher than the global averages, which are expected to

be 2.4 percent and 3.1 percent in the respective periods. The high growth rates will be in the Southeast Asian and South Asian economies and in China, where electrification rates are still low but will increase during the next decade. High economic growth rates in the Southeast Asian countries during the outlook period will further accelerate the growth of electricity demand in the region. In contrast, the growth rates of electricity generation are relatively low in the more mature economies, such as the OECD Pacific and newly industrialized economies (NIEs), because high electrification rates have already been achieved in all economic sectors (see Table 3.12).

Total electric power generation in the Asia-Pacific region is expected to increase from 2,668.6 terawatt hours (TWh) in 1993 to 4,135.6 TWh in 2000 and 6,958 TWh in 2010 (see Table 3.13). Of the 2010 total, 3,469.9 TWh will be generated

Table 3.12 Electricity generation by economic group, 1980–93, with projections to 2010

	Generation (terawatt hours)					Growth rate (%)		
Economic group	1980	1990	1993	2000	2010	1993–2000	2000–2010	1993–2010
OECD Pacific	633.1	942.7	983.3	1,172.9	1,412.1	2.6	1.9	2.2
NIEs	96.9	232.7	299.8	463.3	729.1	6.4	4.6	5.4
South Asia	130.0	304.5	398.2	683.3	1,380.7	8.0	7.3	7.6
Southeast Asia	48.5	125.1	169.9	353.0	833.2	11.0	9.0	9.8
China	300.6	621.2	816.0	1,461.2	2,599.8	8.7	5.9	7.1
Pacific Islands	0.7	1.2	1.4	1.9	3.1	4.5	5.0	4.8
Total Asia-Pacific	1,209.8	2,227.4	2,668.6	4,135.6	6,958.0	6.5	5.3	5.8

Table 3.13 Asia-Pacific electricity generation by energy source, 1980–93, with projections to 2010 (terawatt hours)

Energy source	1980	1990	1993	2000	2010
Oil	424.7	386.8	410.6	344.9	333.8
Gas	94.2	250.4	312.8	520.0	962.8
Coal	342.7	923.3	1,199.8	2,135.6	3,469.9
Hydro	247.2	365.1	413.5	605.6	1,166.0
Nuclear	96.8	291.9	321.2	499.8	952.6
Geothermal	4.2	9.9	10.5	28.1	66.8
Others	0.0	0.0	0.2	1.6	6.1
Total Asia-Pacific	1,209.8	2,227.4	2,668.6	4,135.6	6,958.0

by coal, 1,166.0 TWh by hydropower, 952.6 TWh by nuclear fuel, 962.8 TWh by natural gas, 333.8 TWh by oil, and the remainder by geothermal and other renewable forms of energy.

The fuel mix for power generation in the region during the outlook period is not expected to differ greatly from the current pattern (see Figure 3.15). Coal will continue to be the major fuel in the power sector. In our projections, its share in total generation will increase from 45.0 percent in 1993 to 49.9 percent in 2010. Consumption of oil in the power

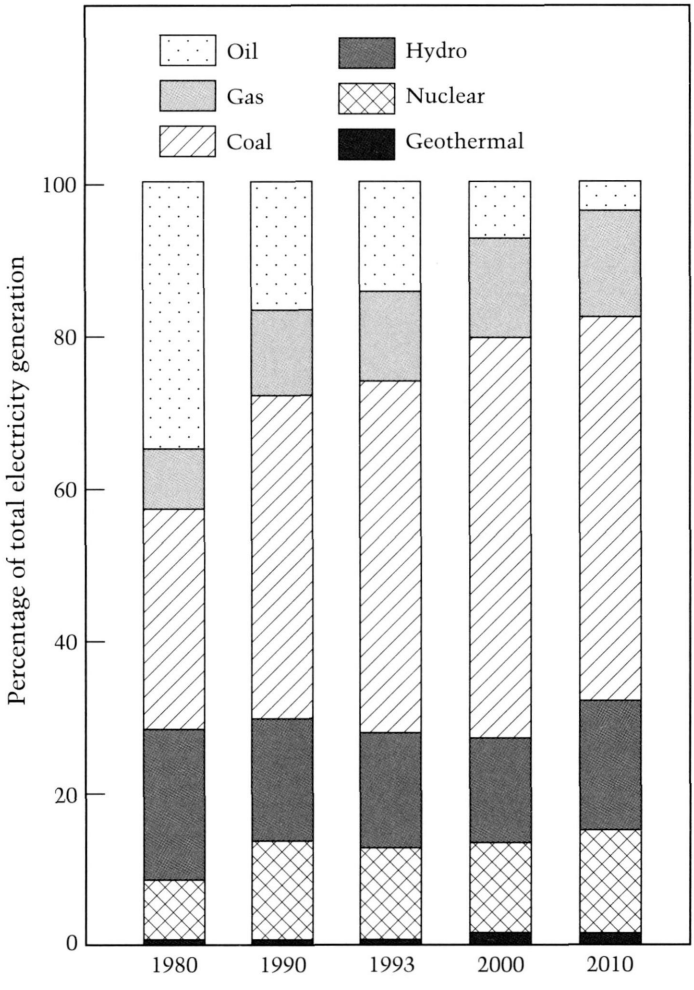


Figure 3.15 Shares of Asia-Pacific electricity generation by fuel type, 1980–93, with projections to 2010

Table 3.14 Shares of Asia-Pacific electricity generation by energy source, 1980–93, with projections to 2010 (%)

Energy source	1980	1990	1993	2000	2010
Oil	35.1	17.4	15.4	8.3	4.8
Gas	7.8	11.2	11.7	12.6	13.8
Coal	28.3	41.5	45.0	51.6	49.9
Hydro	20.4	16.4	15.5	14.6	16.8
Nuclear	8.0	13.1	12.0	12.1	13.7
Geothermal	0.3	0.4	0.4	0.7	1.0
Others	<0.1	<0.1	<0.1	<0.1	0.1

Note: Rounding errors occur.

sector is forecast to drop from 15.4 percent in 1993 to 8.3 percent in 2000 and 4.8 percent in 2010. The shares of nuclear power and gas will increase from 12.0 percent and 11.7 percent, respectively, in 1993 to about 13.8 percent each in 2010. The share of hydropower in total generation will increase from 15.5 percent in 1993 to 16.8 percent in 2010 (see Table 3.14).

THERMAL POWER

Fossil fuels are the main sources of energy in the Asia-Pacific region, and these fuels account for about 70 percent of total power generation. Before the second oil crisis, the share of oil was about 35.5 percent of the regional total and more than 70 percent of the totals in both the Southeast Asian economies and the NIEs. After the oil crisis, most countries tried to reduce oil imports and switch to other energy sources that are available domestically. In Indonesia, however, oil is still the main fuel for power generation, since the country has abundant oil reserves. To make more oil available for export, Indonesia is reducing the share of oil in power generation by introducing coal instead. Other Southeast Asian countries have likewise begun to use coal, and they have also begun to use natural gas. In Taiwan and South Korea, some of the oil share of power generation has been displaced by gas, coal, and nuclear power. Hong Kong has switched away from oil. It currently relies almost entirely on domes-

tic coal fired and imported nuclear power generation for its base load requirements, and it will be adding capacity fired by natural gas.

The shift from oil to other energy sources will continue during the outlook period, and the oil share of power generation will decline substantially in almost every country (see Figure 3.16). Total generation from oil is expected to decline from 410.6 TWh in 1993 to 344.9 TWh in 2000 and 333.8 TWh in 2010 (see Table 3.15). Most countries of the region are making efforts to reduce oil consumption to less than 10 percent of total generation by the year 2010. Oil will continue to play a major role in the Pacific Islands, however, because of the lack of economically viable alternatives for power generation.

Coal will account for the largest share of the substitu-

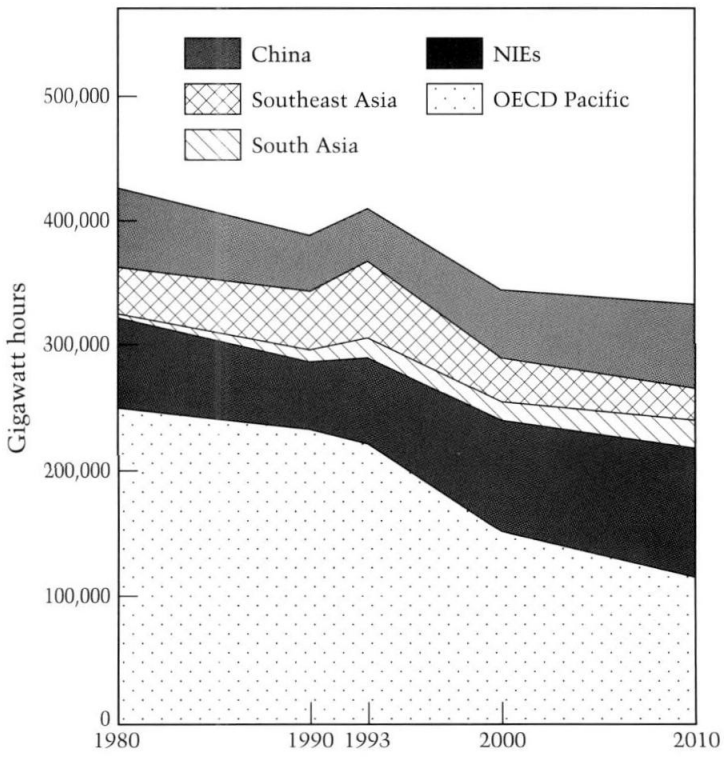


Figure 3.16 Shares of Asia-Pacific oil fired electricity generation by economic group, 1980–93, with projections to 2010

Table 3.15 Oil fired generation, 1980–93, with projections to 2010 (terawatt hours)

Economic group	1980	1990	1993	1995	2000	2010
OECD Pacific	249.6	232.5	221.2	199.6	153.0	113.8
NIEs'	71.8	55.0	70.0	87.3	88.1	103.7
South Asia	1.1	8.2	15.9	14.5	12.3	23.4
Southeast Asia	37.8	46.5	54.8	57.4	35.8	24.5
China	64.0	44.5	48.3	49.8	55.0	67.0
Pacific Islands	0.4	0.2	0.4	0.5	0.7	1.4
Total Asia-Pacific	424.7	386.9	410.6	409.1	344.9	333.8

tion away from oil. Coal is the most economical fossil fuel and has the advantage of supply stability, because coal deposits are both abundant and widely distributed in the region.

Coal will continue to be the main fuel used for power generation in the region throughout the outlook period. Australia, China, and India together accounted for 81.2 percent of the region's total coal fired generation in 1993 (see Figure 3.17). An important factor that will drive the growth of coal demand is China's plan to increase its coal fired installed capacity from 118.0 gigawatts (GW) in 1993 to 219.4 GW in 2000 and 411.1 GW in 2010. More than two-thirds of the electricity generated at present in Australia, China, Hong Kong, and India is produced by coal fired plants. In Hong Kong and India, although coal consumption will continue to rise, the coal share of total generation will decline, because of increases in the use of gas and nonfossil energy sources for power generation. By the year 2010, coal will account for more than 50 percent of total generation in Indonesia and possibly in Thailand. Taiwan is now considering coal fired power plants as an alternative to nuclear plants to serve base load. Sri Lanka plans to open its first coal fired power plant by 2000 with a capacity of 300 megawatts (MW).

Coal fired generation in the region is expected to grow by an annual average of 8.6 percent during 1993–2000 and 5.0 percent during 2000–2010. A total of about 1,199.9 TWh was generated in the region in 1993 using coal as a fuel, and coal fired generation is projected at 2,135.6 TWh in 2000 and 3,469.9 TWh in 2010 (see Table 3.16).

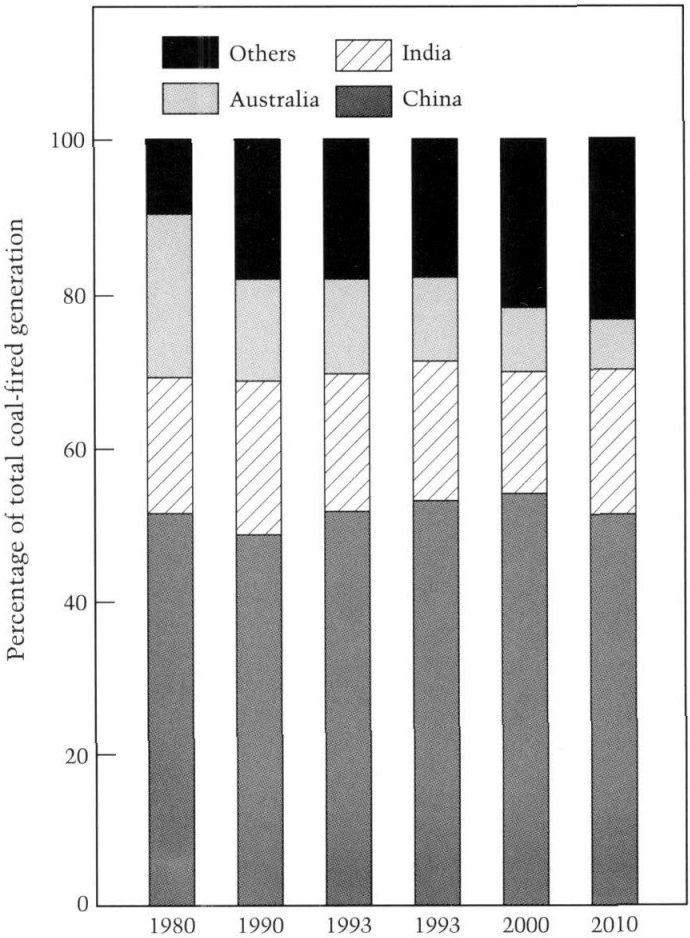


Figure 3.17 Shares of Asia-Pacific coal fired electricity generation by country, 1980–93, with projections to 2010

Table 3.16 Coal fired generation, 1980–93, with projections to 2010 (terawatt hours)

Economic group	1980	1990	1993	1995	2000	2010
OECD Pacific	95.0	192.7	220.7	234.0	316.3	367.8
NIEs	8.4	68.5	102.0	118.7	158.8	246.2
South Asia	60.7	187.7	224.3	263.7	368.8	715.4
Southeast Asia	1.4	26.9	36.2	47.7	154.3	380.5
China	177.1	447.5	616.7	742.0	1,137.3	1,760.0
Pacific Islands	0.0	0.0	0.0	0.0	0.0	0.0
Total Asia-Pacific	342.8	923.3	1,199.9	1,406.1	2,135.6	3,469.9

Note: Rounding errors occur.

The share of gas in the region's power sector as a whole will increase throughout the outlook period. Generation from gas is expected to increase from 312.9 TWh in 1993 to 520.0 TWh in 2000 and 962.8 TWh in 2010 (see Table 3.17), reflecting average annual growth rates of 7.5 percent during 1993–2000 and 6.4 percent during 2000–2010. In some countries, however, where gas has been replaced by other fuels, the share of gas in total generation has declined.

The major consumers of gas for power generation are the OECD Pacific nations, among which Japan alone accounted for 62.1 percent of the region's total gas fired generation in 1993. Because of Japan's policy to reduce oil use in the power sector, the share of oil in total generation has declined, and the share of natural gas has risen. Despite Japan's increased use of natural gas, oil is still the main fuel for power generation, and oil is still the dominant fuel in the Japanese energy sector as a whole.

Among the OECD Pacific countries, the share of gas in total electricity generation will increase throughout the outlook period only in Australia. New Zealand's gas fired generation will reach a peak in 2005. Subsequently, as domestic gas reserves become depleted, New Zealand's gas fired plants will be replaced by coal fired plants. The share of natural gas will decline in Japan, too, by a small percentage, because of the expected big increase in nuclear power. The NIEs will increase gas fired generation from 24.7 TWh in 1993 to 67.7 TWh in 2000 and 120.3 TWh in 2010. Hong Kong expects to begin operating its first gas fired plant (625 MW) in 1996 us-

Table 3.17 Gas fired generation, 1980–93, with projections to 2010 (terawatt hours)

Economic group	1980	1990	1993	1995	2000	2010
OECD Pacific	85.3	187.4	194.3	223.1	253.2	260.2
NIEs	0.0	11.3	24.7	31.5	67.7	120.3
South Asia	7.6	24.6	39.7	48.6	62.4	133.7
Southeast Asia	0.0	24.5	50.9	71.6	105.7	306.4
China	1.3	2.5	3.3	4.8	31.0	142.2
Pacific Islands	0.0	0.0	0.0	0.0	0.0	0.0
Total Asia-Pacific	94.2	250.4	312.9	379.6	520.0	962.8

Note: Rounding errors occur.

ing natural gas from the South China Sea. Large increases are also expected in gas use by the power sector in Southeast Asia and South Asia. More LNG will be used in the power sector, not only by the current consumers (Japan, South Korea, and Taiwan) but also by potential consumers such as China, India, and Thailand.

In 1993 the region's combined electricity generation from fossil fuels alone was 1,923.4 TWh, and the shares of the fuels in the fossil fired generation were 62.4 percent coal, 21.3 percent oil, and 16.3 percent natural gas. During the outlook period, the coal and gas shares will increase, and the declining oil share will be overtaken by gas before the turn of the century. In 2000 the combined total of 3,000.5 TWh will be 71.2 percent coal fired, 17.3 percent gas fired, and 11.5 percent oil fired. The 2010 combined total of 4,766.5 TWh will be 72.8 percent coal fired, 20.2 percent gas fired, and 7.0 percent oil fired (see Figure 3.18).

HYDROPOWER

Hydropower is the second largest energy source (after coal) for power generation in the Asia-Pacific region, but it is highly concentrated in only a few countries. China, India, and Japan together account for 76 percent of all hydro generation in the region, and their combined share is expected to increase to 80 percent by 2010. The South Asian countries depend heavily on hydropower, which accounts for more than 90 percent of total generation in both Nepal and Sri Lanka. It is the main domestic resource for power generation in countries such as New Zealand, which has a large potential for hydro development, and in the Pacific Islands, which have no other energy resources that can be exploited economically.

China has the largest hydro capacity in the region, and hydropower is China's second largest electric power resource (after coal). Official plans call for an increase in installed capacity from 45.0 GW in 1993 to 63.2 GW in 2000 and 137.0 GW in 2010. The main areas of hydro development are the upper Huang He (Yellow River) in the north, the Hongshui

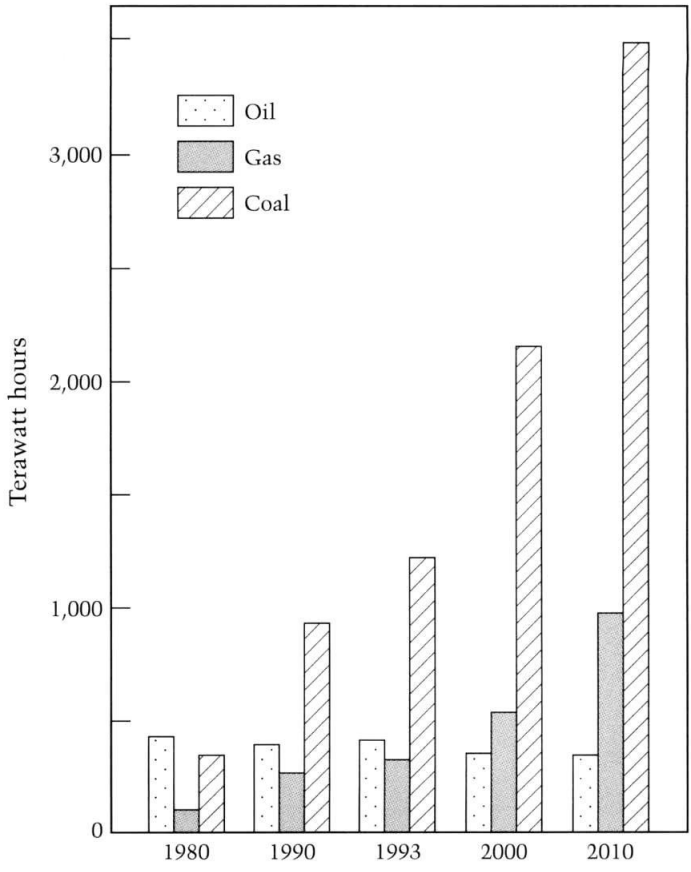


Figure 3.18 Asia-Pacific electricity generation from fossil fuels, 1980–93, with projections to 2010

in the south, and the middle and upper Chang Jiang (Yangtze) in central China, which is the site of the Three Gorges project. This ambitious construction program would increase hydro generation from 146.9 TWh in 1993 to 223.0 TWh in 2000 and 508.0 TWh in 2010.

India's hydro potential is estimated at 84 GW, but about two-thirds of this potential is in the Himalayan mountain range, far from industrial centers. Hydro projects in India have been delayed by a variety of problems, including interstate water disputes and opposition on environmental grounds. Although the government has announced that it will increase the share of hydropower in total generation from 25 percent in 1993 to 40 percent by the time the ninth national develop-

ment plan ends in 2003, such a large increase is not likely to materialize. The hydro generation in India in 1993 was 84.7 TWh. Based on the official forecast, it would be about 302.4 TWh in 2010, at which time it would provide about 27 percent of total generation in the country.

The development of hydropower in Japan has reached a mature stage, and suitable sites are increasingly difficult to identify. Japan plans to increase hydro capacity from 38.6 GW in 1993 to 45.5 GW in 2000 and 57.0 GW in 2010. Pumped storage plants constitute about half of the current capacity, and most of the capacity additions will be pumped storage.

In 1993 hydropower provided only about 4 percent of total generation in the NIEs, whereas it provided more than 10 percent in the other parts of the region. Such a low share is not unusual in economies where land is scarce and population densities are high. Two of the NIEs (Hong Kong and Singapore) have no domestic hydro resources at all. In 1993 South Korea's utility had 2.5 GW and Taiwan's had 2.56 GW of installed hydro capacity, and each utility generated 6.0 TWh of electricity from its hydro plants. The plans of both utilities include a doubling of hydro capacity between 1993 and 2010, but there are too many uncertainties beyond the turn of the century to make such projections with any accuracy.

The Southeast Asian countries are planning big increases in hydro capacity. Indonesia has the most ambitious hydro development program and plans to increase hydro capacity from 2.4 GW in 1993 to 5.1 GW in 2000 and 8.9 GW in 2010. According to utility projections, the combined hydro capacities of Malaysia, the Philippines, and Thailand will double between 1993 and 2010.

In the Pacific Islands, hydropower is the only domestic energy resource that is economically viable. In 1993, it constituted 47 percent of total capacity and provided 69 percent of total generation. Total hydro capacity in the islands is expected to grow from a small base of 261 MW in 1993 to 394 MW in 2010. More than 80 percent of the existing capacity is in Fiji and Papua New Guinea. Most of the generation in

Table 3.18 Hydro generation, 1980–93, with projections to 2010 (terawatt hours)

Economic group	1980	1990	1993	1995	2000	2010
OECD Pacific	119.0	125.5	121.2	125.6	135.4	169.5
NIEs	4.9	13.4	12.0	13.3	15.5	21.7
South Asia	57.5	77.9	111.2	130.3	195.5	392.3
Southeast Asia	7.3	20.6	21.2	26.1	35.0	72.8
China	58.2	126.7	146.9	163.7	223.0	508.0
Pacific Islands	0.3	0.9	1.0	1.0	1.2	1.7
Total Asia-Pacific	247.2	365.1	413.5	460.0	605.6	1,166.0

Note: Rounding errors occur.

these two countries and in Western Samoa is hydropower. The utilities in the other islands rely mostly on diesel.

The outlook for hydro development is much better in the Asia-Pacific region than in the rest of the world. The average annual growth rate of hydro generation in the region is projected at 5.6 percent during 1993–2000 and 6.8 percent during 2000–2010. The region's hydro generation is expected to increase from 413.5 TWh in 1993 to 605.6 TWh in 2000 and 1,166.0 TWh in 2010 (see Table 3.18).

NUCLEAR POWER

Nuclear power is increasingly being rejected in western countries, but it may have a relatively bright future in the Asia-Pacific region—the only region in the world that is adding nuclear capacity. To meet the very rapid electricity demand growth that is accompanying the region's booming economic growth, some countries are pursuing the nuclear option, primarily because the preference for relative self-sufficiency outweighs cost factors. Public resistance is the biggest constraint on nuclear development, and it will keep future nuclear capacity additions below the levels currently projected.

China, India, Japan, North Korea, Pakistan, South Korea, and Taiwan currently have nuclear power programs. In 1993 their combined nuclear capacity (excluding North Korea) was 55.3 GW, and their combined nuclear generation was about 321.2 TWh. In addition to these seven, only one

new program, in Indonesia, is expected during the outlook period. Thailand was planning to bring its first (2 GW) nuclear plant on line by 2006, but safety concerns and public opposition have obliged the government to postpone its nuclear project until at least 2011.

In 1993 Japan's nuclear capacity was 38.4 GW, its nuclear generation was 222.3 TWh, and Japan accounted for 69.3 percent of all nuclear generation in the region. Japan's goal is to increase its nuclear capacity to 72.0 GW by the end of the outlook period. Nuclear development will, however, be constrained by public resistance, the country's declining economic growth rate, and demand that will probably be dampened by energy conservation. Japan's nuclear capacity will therefore probably not exceed 70.0 GW in 2010.

South Korea and Taiwan are the region's only two NIEs that have domestic nuclear plants. Hong Kong likewise relies on nuclear power but imports its supply from its jointly owned nuclear plant in China. In 1993 South Korea's nuclear plants generated 58.1 TWh, which was 40 percent of total generation. This percentage is expected to rise, because new nuclear units are scheduled for completion each year from now until after the turn of the century. Taiwan's nuclear plants generated 33.0 TWh in 1993, which was 33 percent of total generation. The percentage in Taiwan will decline in the short term, because no new units will come on line before the turn of the century. The utilities are expected to increase nuclear capacity in South Korea from 7.6 GW in 1993 to 20.4 in 2004 and in Taiwan from 5.1 GW in 1993 to 7.2 GW in 2004. Projections from 2004 to the end of the outlook period, however, are speculative. The official forecasts for 2010 are 24.5 GW in South Korea and 11.1 GW in Taiwan.

China had no nuclear capacity on line in 1990 but it is currently operating two nuclear plants. The 300 MW in Zhejiang Province is owned by the Chinese government, and the 1,800 MW Daya Bay plant near Hong Kong is a joint venture with the Hong Kong utility. China will increase its nuclear capacity to 3.5 GW in 2000 and 5.3 GW in 2004. The

official projection for 2010 is 22.3 GW. The new plants will be in east China, Liaoning Province, and Guangdong Province, where coal and hydro resources are inadequate to meet local power generation needs.

Most of South Asia's nuclear capacity in 1993 was in India (1.8 MW), and the remainder was in Pakistan (139 MW). India will have 4.0 GW of nuclear capacity on line by 2004, and Pakistan will have 439 MW. Official projections, however, are forecasting combined South Asian nuclear capacity at 27.1 GW in 2010.

The Indonesian government has invited bids for the construction of its first nuclear power plant, which will be central Java. It hopes to begin construction in 1996 and to bring the first unit (600 MW) on line by 2003. Delays can be expected, and the state utility does not yet include nuclear generation in its projections for 2010. During the following twenty-five years, the government proposes to build twelve nuclear power plants on Java, each with a capacity of 600–1,000 MW. These additions would help the state utility and the country's large cogeneration sector to cope with Indonesia's rapid and almost overwhelming increases in electricity demand.

The region's total nuclear capacity will still be growing in 2004, although projections beyond that year are speculative. If all planned projects are included, nuclear generation in the region would be growing at an average annual rate of 6.6 percent and would increase from 321 TWh in 1993 to 953 TWh in 2010. About half of the 2010 generation would be in Japan (478 TWh), followed by South Korea (173 TWh), China (123 TWh), India (95 TWh), Taiwan (64 TWh), and Pakistan (20 TWh) (see Figure 3.19).

GEOTHERMAL POWER

Only 0.5 percent of total power generation in the Asia-Pacific region is provided by geothermal power plants, and most of the capacity is in Southeast Asia. In 1993 the Philippines had 1.1 GW of geothermal capacity (56.3% of the region's

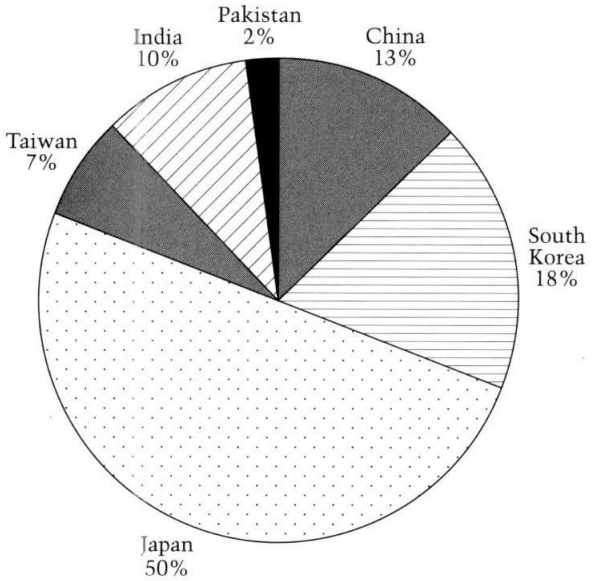


Figure 3.19 Structure of Asia-Pacific nuclear generation, 2010

total) and generated about 5.6 TWh (53.9% of the region's total geothermal generation). Two OECD Pacific countries (New Zealand and Japan) together had about 560 MW of geothermal capacity and generated about 3.6 TWh of electricity from this source in 1993.

Indonesia has the world largest geothermal reserves: a potential of about 16.0 GW. Only 273 MW has been developed thus far, although the country's total geothermal capacity in 2010 is projected at 10.2 GW. The Indonesian government wants to increase the use of its geothermal resources and currently allows wholly foreign-owned companies to undertake build-operate-transfer projects. The Asia-Pacific region's total geothermal generation in 2010 is projected at 66.8 TWh; 56 percent (36.8 TWh) of the total will be generated in the Philippines, 22 percent (15 TWh) in Japan, 18 percent (12.3 TWh) in Indonesia, and 4 percent (2.8 TWh) in New Zealand (see Figure 3.20)

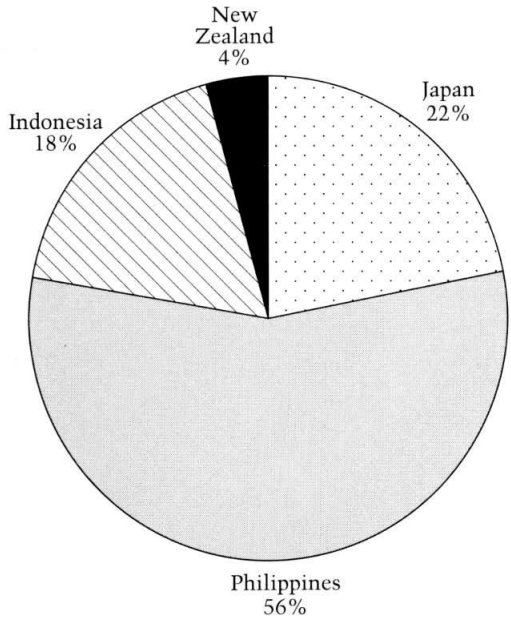


Figure 3.20 Structure of Asia-Pacific geothermal generation, 2010

OTHER RENEWABLE RESOURCES

The development of renewable resources for power generation is actively pursued on a large scale in only two nations in the region. In India, about 167 GWh of electricity was generated in 1993 from power plants that make use of renewable energy such as wind, biomass cogeneration, solar energy, and biotechnology. Various financial incentives are provided to encourage private investors to develop renewable energy. The generation from renewable resources in India is expected to increase to 566 gigawatt hours (GWh) in 2000 and to 1,113 GWh in 2010. In Japan, renewable resources such as waste fired, photovoltaic, and wind power are being developed, and the installed capacity of these renewable resources is targeted at 520 MW in 2000 and 1,800 MW in 2010. About 500 MW in 2000 and 1,600 MW in 2010 will be waste fired plants; photovoltaic and wind powered plants will ac-

count for 10 MW each in 2000 and 100 MW each in 2010. Japan's generation from these plants is expected to be 1,000 GWh in 2000 and 5,000 GWh in 2010.

China and the Former Soviet Union

China is the world's third largest energy producer and consumer, and the former Soviet Union (FSU) is the world's second largest. Energy developments in these two economies will have major impacts on international markets and especially on the markets of the Asia-Pacific region, but it is extremely difficult to project changes in their energy sectors with a high degree of accuracy. Any attempt to project supply and demand in either China or the FSU must take into account major uncertainties. The most important ones are: (1) the lack of consistent and comprehensive data on energy resources, (2) the heavy dependence of both economies on foreign technology and investment for future energy-sector development, (3) infrastructure constraints and their effects on the energy sector, and (4) national policies such as energy pricing, which can create serious market distortions. The tentative outlook presented in this chapter is based on our current assessment of these and related issues. There is no doubt that, as the database improves and solutions to other problems are found, the projections will have to be altered significantly.

PEOPLE'S REPUBLIC OF CHINA

China has an abundance of coal, oil, and hydropower, and its potential reserves of natural gas are believed to be substantial. Coal dominates the energy supply, providing 77 percent of total primary energy in 1993. China is currently the world's largest coal producer (1,141 million tonnes in 1993), and the country is richly endowed with coal reserves. Coal reserves are officially estimated at about 1,000 billion tonnes, but if western definitions are applied, the reserves are probably in

the range of 200–300 billion tonnes (Table 4.1). Coal deposits exist in almost all provinces, but more than three-quarters of the reserves are in the northern part of the country, mainly in the provinces of Shanxi, Shaanxi, Xinjiang, and Inner Mongolia. The quality of the coal is much better in the north than in the south. While China has been trying to develop coal resources in some southern provinces, near the coastal areas where the economy is growing rapidly, most of the production during the outlook period to 2010 will be in the north.

The development of China's modern oil industry dates from the late 1950s, when the Daqing oil field was discovered in the Songliao Basin of northeast China. After more than three decades of development, China has become the world's sixth largest oil producer. In 1993 China produced 2.9 million barrels of oil per day, which accounted for about 19.4 percent of the country's total primary energy production. China had an estimated 24 billion barrels of proven oil reserves in 1993, or about 2.4 percent of world reserves. The domestic refining industry underwent a transformation during the decade and a half after China opened its door to the outside world in 1978. As a result of heavy investment in refining, together with the infusion of new foreign technology, China's primary distillation capacity (3.3 million barrels per day in 1993) has become the fifth largest in the world. The refining industry's conversion capability is likewise im-

Table 4.1 China's energy reserves, production, and consumption, 1993

Energy source	Reserves	Production	Consumption
Oil	24 billion barrels	2.9 million barrels per day	3.1 million barrels per day
Natural gas	u	15.4 billion cubic meters per year	15.4 billion cubic meters per year
Coal	200–300 billion tonnes	1.14 billion tonnes per year	1.11 billion tonnes per year
Hydro	378 gigawatts	146.9 terawatt hours per year	146.9 terawatt hours per year

u = data unavailable.

pressive. Further big expansions in the refining industry are planned, but only marginal increases are expected in domestic crude oil production. China is a net importer of oil products and will probably become a net importer of crude oil in 1995 or 1996.

China has not yet compiled a comprehensive estimate of its natural gas reserves because, until recently, natural gas was overlooked as a significant source of energy. Some economists argue that the potential reserves are substantial. For many years, only about 2 percent of total primary energy production has been natural gas. China produced 1.6 billion cubic feet of natural gas per day in 1993. About 40 percent of the production was in Sichuan Province, and most of the natural gas produced elsewhere was associated gas from oil fields.

China has the world's largest potential for hydro development, estimated at 378 gigawatts (GW). A majority of these hydro resources are located in the southwestern provinces. Currently, China has about 45 GW of hydro capacity which generated 146.9 terawatt hours (TWh) of electricity in 1993. Developing hydropower is one of the government's main priorities. The Ministry of Power Industry plans to add nearly 40 GW of new hydro capacity by 2000. A total of about 90 GW of large hydro projects (each with a capacity exceeding 2 GW) is currently in the planning stage. Although about 25 GW of hydro capacity has been installed since 1980, the share of hydro in total capacity has decreased. The major factors impeding hydro exploitation are the high capital costs of hydro projects, the great distances between major resources and load centers, decentralization of the power industry, and limits on the rates of return to investors.

In the past forty years, China's primary energy demand has increased 8.1 percent per year, reaching 15.5 million barrels of oil equivalent per day in 1993. During this period, the pace of energy demand growth changed dramatically in relation to economic growth. From 1953 to 1978, energy consumption increased at a rate of 9.9 percent per year, while

GDP grew at a slower rate (only 5.7%), resulting in an energy demand elasticity of 1.74. Subsequently, this pattern was reversed. During 1978–93, the average annual growth rates of energy consumption and GDP were 4.9 percent and 9.2 percent, respectively, and the energy demand elasticity dropped to 0.53. At least three major factors contributed to this drop. First, the growth rates of light industry and agriculture increased during 1978–93, while the growth rate of heavy industry (which is 3.6 times as energy-intensive as light industry) decreased. Second, one of the main reasons for the rapid economic growth in China since 1978 is the infusion of foreign technology. By adopting new energy technologies that have substantially reduced energy consumption in developed countries, China's industrial firms have been able to use energy more efficiently. Third, the energy price reform, which was phased in during the early 1980s, produced substantially higher marginal prices and may have stimulated some energy conservation.

Under the base case scenario, it is assumed that GDP will grow at a rate of 8.5 percent per year from 1993 to 2000 and at 6.3 percent from 2000 to 2010 (Table 4.2). The economic structure will change significantly during this period. The share of agriculture in GDP will decrease from 18 percent in 1993 to 12.6 percent in 2000 and 9.1 percent in 2010, while the share of services will increase from 28 percent in 1993 to 30.9 percent in 2000 and 39.0 percent in 2010. Primary energy consumption is projected to grow at average annual rates of 4.4 percent during 1993–2000 and 3.3 percent during 2000–2010. The growth rate of energy demand is expected to be higher during 1993–2000 than it will be during the next decade, for reasons that include more rapid economic growth, increasing urbanization, and expanding road transportation in the 1990s. After the turn of the century, the structure of China's economy will move toward services, and population growth will become slower.

China's energy demand elasticity is expected to remain low, and energy intensity will continue to decrease during the outlook period. The main reasons for these trends are the

Table 4.2 China's GDP by sector, 1980–93, with projections to 2010

	GDP (billion US$ at 1993 prices)					Growth rate (%)				
Sector	1980	1990	1993	2000	2010	1980–90	1990–93	1993–2000	2000–2010	1993–2010
Agriculture	49.7 (32.0)	80.3 (22.0)	91.1 (18.0)	113.2 (12.6)	152.2 (9.2)	4.9	4.3	3.2	3.0	3.1
Industry	73.0 (47.0)	186.1 (51.0)	273.2 (54.0)	505.1 (56.4)	862.8 (52.3)	9.8	13.6	9.2	5.5	7.0
Services	32.6 (21.0)	98.5 (27.0)	141.6 (28.0)	277.1 (30.9)	634.6 (38.5)	11.7	12.9	10.1	8.6	9.2
Total GDP	155.4 (100.0)	364.9 (100.0)	505.9 (100.0)	895.4 (100.0)	1,649.6 (100.0)	8.9	11.5	8.5	6.3	7.2

Note: Figures in parentheses are percentage sectoral shares of total GDP. Rounding errors occur.

transition to a market economy, in which resources will be used more efficiently, and the shift to services, which have low energy intensities. Energy demand after 2000 will slow down and shift to the more efficient forms of energy, such as electricity and light oil products. These changes are reflected in the projections of energy demand provided in Table 4.3 and Figure 4.1.

Coal will continue to dominate the energy sector during the outlook period, but its share of primary energy consumption will decrease from 76.7 percent in 1993 to 72.8 percent in 2000 and 63 percent in 2010. The power generation sector will become an increasingly important market for coal during this period. Consumption of coal in power stations is expected to increase by an average of 6.1 percent per year until the end of the outlook period. In 1993 only 28.8 percent of all coal consumed in China was used for power generation, but this share will swell to 51.5 percent in 2010.

Oil demand is expected to increase by an average of 5.1 percent per year during 1993–2010, and the oil share of final energy demand will increase from 22.5 percent in 1993 to about 30 percent in 2010. The transportation sector is expected to grow rapidly, at an average annual rate of about 10 percent during the outlook period, and China's oil demand will therefore continue to shift to light oil products. An increasing amount of oil will be imported; oil import dependence (the percentage of net oil imports in total oil demand) is expected to increase from less than 5 percent during the two-year period 1993–94 to 21 percent in 2000 and 47 percent in 2010. Demand for natural gas will be dampened by China's infrastructure constraints; therefore, although gas consumption will grow much faster in the future than it has in the past, its share of primary energy consumption will still be very low.

Electricity demand is projected to grow at rates of 8.7 percent per year during 1993–2000 and 5.9 percent during 2000–2010. Coal will continue to be the major resource for power generation, but the proportion of electricity generated by coal will decrease from 75.6 percent of the total in 1993 to

Table 4.3 China's energy demand, 1980–93, with projections to 2010

Item	Demand					Growth rate (%)				
	1980	1990	1993	2000	2010	1980–1990	1990–1993	1993–2000	2000–2010	1993–2010
	Thousand barrels of oil equivalent per day									
Primary energy	8,220.1	13,278.0	15,500.9	20,765.3	28,407.9	4.9	5.3	4.3	3.2	3.6
Coal	6,088.0	10,488.0	11,880.0	15,286.0	18,272.0	5.6	4.2	3.7	1.8	2.6
Oil	1,770.0	2,288.0	3,078.0	4,510.0	6,862.8	2.6	10.4	5.6	4.3	4.8
Gas	262.0	284.0	286.0	508.0	1,760.0	0.8	0.2	8.6	13.2	11.3
Nuclear	0.0	0.0	4.2	77.7	639.2	na	na	51.9	23.5	34.4
Hydro	100.1	218.0	252.7	383.6	873.9	8.1	5.1	6.1	8.6	7.6
Final energy	6,706.3	10,437.1	11,921.3	15,397.8	20,710.0	4.5	4.5	3.7	3.0	3.3
Coal	4,610.7	7,211.5	7,624.2	8,587.2	8,973.5	4.6	1.9	1.7	0.4	1.0
Oil	1,375.4	1,941.4	2,679.5	3,876.0	6,288.0	3.5	11.3	5.4	5.0	5.1
Gas	202.6	214.5	212.6	265.9	971.8	0.6	-0.3	3.3	13.8	9.4
Electricity	517.6	1,069.7	1,405.1	2,516.1	4,476.8	7.5	9.5	8.7	5.9	7.1
Other demand	542.1	822.6	974.0	1,337.5	1,803.6	4.3	5.8	4.6	3.0	3.7
	Terawatt hours per year									
Electricity input	1,579.2	3,202.2	4,163.3	6,651.8	10,201.7	7.3	9.1	6.9	4.4	5.4
Electricity output	300.6	621.2	816.0	1,461.2	2,599.8	7.5	9.5	8.7	5.9	7.1
Coal	177.1	447.5	616.7	1,137.3	1,760.0	9.7	11.3	9.1	4.5	6.4
Oil	64.0	44.5	48.3	55.0	67.0	-3.6	2.8	1.9	2.0	1.9
Gas	1.3	2.5	3.3	31.0	142.2	6.8	9.7	37.7	16.5	24.8
Nuclear	0.0	0.0	0.8	14.9	122.6	na	na	51.9	23.5	34.4
Hydro	58.2	126.7	146.9	223.0	508.0	8.1	5.1	6.1	8.6	7.6
	Barrels of oil equivalent per year									
Energy per capita	3.1	4.3	5.0	6.2	8.0	3.4	5.3	2.9	2.6	2.8
	Barrels of oil equivalent per US$1,000 per year									
Energy intensity	19.6	13.5	11.4	8.6	6.4	-3.7	-5.6	-3.9	-2.9	-3.3

na = not applicable.

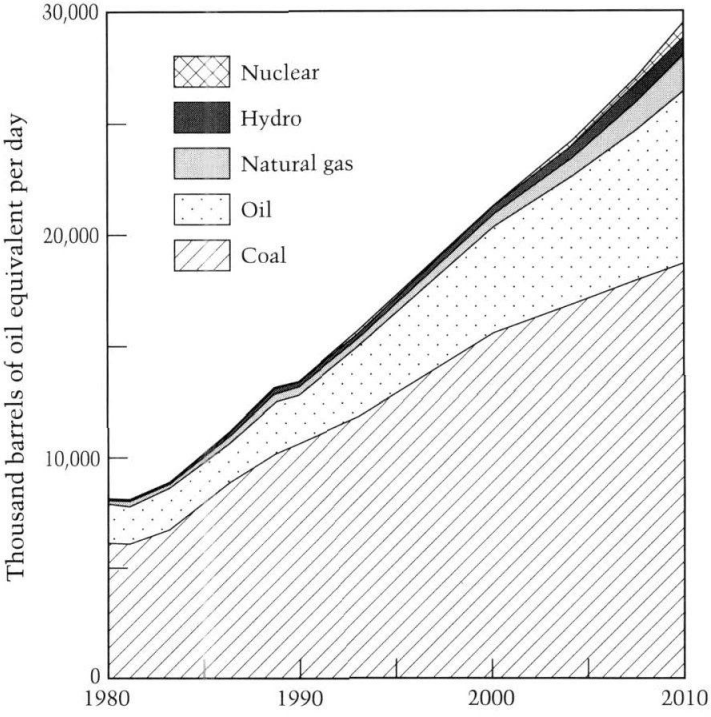


Figure 4.1 Energy demand in China by energy source, 1980–93, with projections to 2010

67.7 percent in 2010. Nuclear and hydro capacities are expected to expand substantially after the turn of the century, accounting for 4.7 percent and 19.5 percent, respectively, of total generation in 2010. Natural gas use in the power sector will increase substantially and will provide an estimated 5.5 percent of total generation in 2010.

NEWLY INDEPENDENT STATES

The countries of the former Soviet Union are collectively called the newly independent states (NIS) in this study. Despite the continuous decline of their energy output in recent years, they still retain their position, if grouped together, as one of the world's largest producers, consumers, and exporters of commercially traded fuels. In 1993 they provided about

8 percent of world exports of liquid fuels (crude oil and products) and 30 percent of internationally traded supplies of natural gas. Furthermore, the NIS are believed to be endowed with the world's largest recoverable resources of fossil fuels. At the end of 1993, they accounted for considerable shares of the estimated proven reserves remaining in the ground: almost 6 percent of oil, more than 23 percent of coal, and nearly 40 percent of natural gas.

The NIS will play an important role in shaping the future global energy balance and, in particular, the balance in the Asia-Pacific region. Because of current economic and political uncertainties, however, the potential energy interflows between the NIS and the rest of the world are difficult to predict. Projections of these interflows therefore become key assumptions of any related projections, either regional or global.

The base case scenario assumes that the NIS as a region will be a net exporter of the main internationally tradable energy resources (oil, gas, and coal), with an aggregate exportable surplus of 5.7 million barrels of oil equivalent per day in 2000 and 7.3 million in 2010 (see Table 4.4 and Figure 4.2). At the beginning of the 1990s, the Soviet Union ceased to be a net exporter of electricity, and in 1993 gross imports of electricity exceeded gross exports by some 20 TWh. During the outlook period to 2010, domestic and intrabloc supplies are expected to keep the NIS's electricity consumption roughly in balance, and no net exports of electricity will be available yet from the NIS as a whole.

Because of the geopolitical position and the existing transport infrastructure of the NIS, the bulk of the fuel exports during the outlook period will be destined for Europe. These exports will therefore have only an indirect influence on the Asia-Pacific region. Nevertheless, some of these exports—notably those originating east of Siberia (i.e., in the Russian Far East)—will find their way directly into the Asia-Pacific markets.

Table 4.4 Production, consumption, and exportable surpluses of oil, natural gas, and coal in the NIS, 1990–93, with projections to 2010

Fuel and status	1990	1993[a]	1995	2000	2005	2010
Oil						
Production						
In million tonnes	571	403	372	460	505	535
In million barrels per day of oil equivalent	11.71	8.26	7.63	9.41	10.36	10.98
Biggest producers (million tonnes)						
Russia	516	355	310	355	370	380
Kazakhstan	26	23	30	48	65	70
Azerbaijan	13	10	12	22	25	27
Consumption						
In million tonnes	425	278	272	310	335	355
In million barrels per day of oil equivalent	8.77	5.73	5.61	6.38	6.91	7.32
Exportable surplus						
In million tonnes	146	125	100	150	170	180
In million barrels per day of oil equivalent	2.94	2.53	2.02	3.03	3.45	3.66
Natural gas						
Production						
In billion cubic meters[b]	815	761	788	900	1,005	1,085
In million barrels per day of oil equivalent	13.38	12.49	12.93	14.74	16.51	17.81
Biggest producers (billion cubic meters)[b]						
Russia	641	618	620	690	755	810
Turkmenistan	88	65	73	90	105	120
Uzbekistan	41	45	48	55	60	65
Consumption						
In billion cubic meters[b]	707	661	673	770	860	925
In million barrels per day of oil equivalent	11.62	10.84	11.06	12.61	14.12	15.19
Exportable surplus						
In billion cubic meters[b]	108	100	115	130	145	160
In million barrels per day of oil equivalent	1.76	1.65	1.87	2.13	2.39	2.63
Coal						
Production						
In million tonnes	703	539	583	610	665	715
In million barrels per day of oil equivalent	6.81	5.22	5.65	5.87	6.50	6.95
Biggest producers (million tonnes)						
Russia	396	305	314	325	340	360
Ukraine	165	116	134	140	145	155
Kazakhstan	131	112	125	135	170	190
Consumption						
In million tonnes	681	511	549	565	600	635
In million barrels per day of oil equivalent	6.54	4.88	5.24	5.32	5.71	5.98
Exportable surplus						
In million tonnes	22	28	34	45	65	80
In million barrels per day of oil equivalent	0.27	0.34	0.41	0.55	0.79	0.97

Note: Conversion to barrels of oil equivalent has been made, taking into account current gross energy content of fuels produced or consumed in different ex-Soviet states and on the basis of the following ratios:

1 barrel of oil equivalent = 5.8 million Btu = 0.144 tonne of oil equivalent

1 tonne of oil equivalent = 40.3 million Btu = 7.414 barrels of oil equivalent

a. Estimated

b. As measured under ex-USSR standard conditions (20° C. and 760 mm Hg).

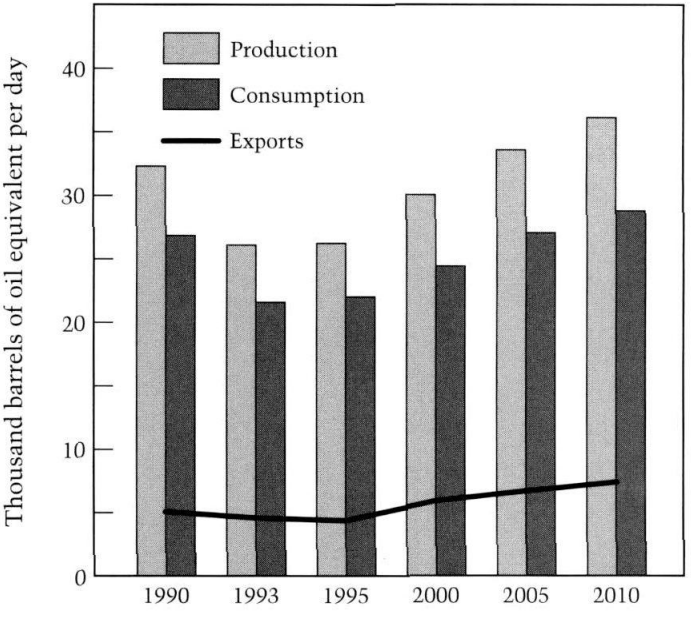


Figure 4.2 Fuel balances of the newly independent (ex-Soviet) states, 1990–93, with projections to 2010

RUSSIAN FAR EAST

The Russian Far East (RFE) is emerging as a major source of energy supplies for the rapidly growing Asia-Pacific energy markets. After the turn of the century, given the ongoing and the already earmarked resource developments, the RFE can substantially increase its self-sufficiency in crude oil, become a marginal exporter of light products (gasoline and jet fuel), restore and strengthen its status as a coking coal supplier, and provide large supplies of natural gas to neighboring Asia-Pacific countries. These changes will not only reshape the matrix of today's Asia-Pacific energy flows but could also help to redesign the patterns of the region's geopolitical relationships.

Under the most probable circumstances, the current heavy dependence of the RFE on outside supplies of crude oil (which were 79% of total 1993 consumption) is likely to decrease to 37 percent by the year 2010 and to 11 percent by 2010. In this base case, net RFE imports of crude oil will fall from 123.2 thousand barrels per day (b/d) in 1993 to less than

80 thousand b/d in 2000 and then shrink to only 30 thousand b/d in 2010. The RFE's projected deficit in main oil products (excluding lube oils, bitumen, and LPG) will decrease from 219.4 thousand b/d in 1993 to 198 thousand b/d in 2000 and 158 thousand b/d in 2010. Sustainable surpluses of coal may appear only after the year 2005, and coal exports will probably be only about 10 million tonnes per year by 2010. In contrast, by the turn of the century, the RFE will have an exportable surplus of natural gas that is both sizable and sustainable: 950 million standard cubic feet per day in 2000 and as much as 1,470 million in 2010 (see Figure 4.3 and Table 4.5).

While emerging as a major natural gas exporter, the RFE will continue to be dependent on imports of crude oil and oil products. This dependence does not mean, however, that no oil will be available for export from the RFE. Most likely, some of the RFE's requirements for crude and products will still be satisfied by supplies from West and East Siberia, and some of the RFE's oil will be acquired by foreign investors in

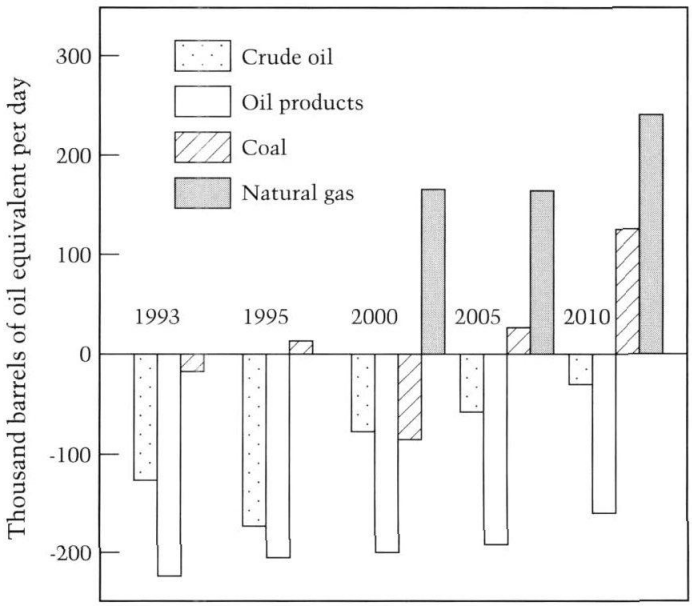


Figure 4.3 Energy surpluses and deficits of the Russian Far East, 1993, with projections to 2010

Table 4.5 Fuel balances of the Russian Far East, 1993, with projections to 2010

Fuel and status	1993[a]	1995	2000	2005	2010
Crude oil[b]					
Production (thousand barrels per day)	34.2	32	132	170	240
Consumption (thousand barrels per day)[c]	157.4	204	209	228	270
Surplus					
In thousand barrels per day	-123.2	-172	-77	-58	-30
In thousand barrels per day of oil equivalent	-124.4	-174	-78	-59	-30
Oil products[d]					
Production (thousand barrels per day)	138.0	183	193	215	252
Consumption (thousand barrels per day)[e]	357.4	387	391	404	410
Surplus					
In thousand barrels per day	-219.4	-204	-198	-189	-158
In thousand barrels per day of oil equivalent	-222.6	-207	-201	-192	-161
Natural gas					
Production (million standard cubic feet per day)	305	380	1,610	1,900	2,850
Consumption (million standard cubic feet per day)[e]	305	380	660	950	1,470
Surplus					
In million standard cubic feet per day	0	0	950	950	1,380
In thousand barrels per day of oil equivalent	0	0	162	162	236
Coal					
Production (million tonnes)	39.0	50	60	70	80
Consumption (million tonnes)[e]	40.3	49	67	68	70
Surplus					
In million tonnes	-1.3	1	-7	2	10
In thousand barrels per day of oil equivalent	-15.6	12	-85	24	122

a. Estimated.
b. Including condensate.
c. Refinery intake, own and direct use, losses, and stocks change.
d. Main products (gasoline, jet fuel, diesel/gas oil, and fuel oil) only.
e. Including own use, losses, and stocks change.

compensation for their participation in upstream and downstream projects. The result could be gross RFE exports of up to 70 thousand b/d of crude and 20 thousand b/d of products in 2000 and up to 140 thousand b/d of crude and 50 thousand b/d of products in 2010. In addition, up to 10 million tonnes per year of high quality Yakutian coking coal could be available for export by the end of this century and up to 20 million tonnes per year in 2010.

It should be borne in mind that the RFE's export-oriented plans for tapping its fuel potential depend greatly on the active participation of foreign investors. Consequently, the foreign trade component of the RFE's fuel balances is tied

extremely closely to foreign involvement in the development of the RFE's energy resources. Export volumes large enough to influence the existing Asia-Pacific markets can be achieved only through close cooperation with other countries of the region. Japan, South Korea, and the United States are now the key players, but Australia, Canada, China, and Taiwan could have important roles to play in developing these resources and providing market outlets.

Energy and the Environment

The fact that emissions harmful to the environment in the Asia-Pacific region will increase significantly throughout our outlook period to the year 2010 cannot be disputed. Even in the low economic growth case, both energy use and emissions are expected to more than double between 1990 and 2010. Just as the availability and use of commercial fuels in the region have led to impressive economic growth, they have also brought about rapid growth of emissions. This section highlights the types of decisions currently faced by policymakers in their attempt to balance economic growth with environmental protection.

INTRODUCTION

Policymakers in the Asia-Pacific region will be asked more and more to set environmental priorities, as their economies continue to grow and environmental conditions decline. Funding requirements for environmental controls have to compete with funding requirements for economic growth, and questions will increasingly be asked concerning the environmental and economic trade-offs involved, for example, in removing the sulfur dioxide from electric power plants versus removing the lead in gasoline used in transportation, or concentrating on improving water quality by curbing industrial and municipal waste emissions into lakes and waterways. Within a given sector such as power generation, decisions must be made among emission types such as sulfur dioxides, nitrogen oxides, and particulate matter.

Once a decision is taken to control a given emission, the degree of control appropriate for a developing country is not clearly defined. When standards are simply adopted from

developed countries, they are often ignored because of their perceived high cost. In the developed countries, the best-available control-technology notion often drives decision making concerning limits on emissions. Also simply known as a technology driven standard, the theory stipulates that emission limitations are set at the maximum level that can be achieved by the application of the best technology that is commercially available. When this approach is applied, emissions often move from an unregulated state to a state with a very high level of control, often with only minor concerns about cost. An alternative is to use a damage based approach, setting emission limitations at the point at which the cost of control equals that of the damage caused by the uncontrolled emissions. While attractive from a least cost standpoint, damage based standards suffer from the difficulty of agreeing on the cause-effect relationship between environmental emissions and effects on human health or the environment (including forests, lakes, and buildings). It was the difficulty of agreeing to such cause-effect relationships that in large part led to the use of technology based standards in developing countries. Thus, if decision makers in the developed countries cannot agree on the appropriate damage based level of controls, it is difficult to see how those from developing countries, with the pressure to promote economic growth, can be expected to do the same.

Another issue in choosing the appropriate level of environmental control is the generally nonlinear and often exponential cost associated with attaining the high levels of controls that have been adopted in the developed countries and are being suggested for the developing countries of the Asia-Pacific region. There are usually significant cost increases as one moves from low levels of control (15–30 percent) to medium levels (50 percent) and to the high levels (greater than 90 percent) typically found in the developed countries. As long as the reductions in damages are uncertain, it will be difficult to convince policymakers to reduce their current emphasis on promoting economic growth at the expense of the environment.

The time frame in which environmental questions are being addressed in the Asia-Pacific region is also important. In the United States and most other developed countries, comprehensive environmental regulations (such as the U.S. National Environmental Policy Act of 1969) did not appear until well after industrialization had been achieved. In the Asia-Pacific region, however, governments are being asked to address environmental concerns during a period of significant economic growth that should lead to industrialization. Their rapid rates of economic growth also mean that the Asia-Pacific countries may have little time to react to changing environmental burdens before significant damage occurs. The challenge facing the developed countries is to develop cleaner technologies that do not carry a high economic cost and to transfer them to the region's developing countries. Hopefully, through the use of such technologies, acceptable balances can be reached between economic growth in the region and the protection of the environment.

CLIMATE CHANGE IMPLICATIONS

The leading environmental focus in recent years has been emissions of CO_2 associated with fossil energy use. This focus is due to the identification of CO_2 as the single most important man-made gas associated with the greenhouse effect—which many people believe may lead to a gradual warming of the global climate and to associated potential impacts such as a rise in the sea level and changes in precipitation patterns. In response to international concern, the governments of many developed countries have pledged to attempt to hold CO_2 emissions at their 1990 levels. The governments of the newly industrialized and developing countries have expressed concern for climate change, but feel that economic development must be considered in the formulation of any climate change response strategy.

Since the environmental implications of energy consumption are significantly dependent upon the particular type of energy chosen, it is important to look at the general trends projected for fuel choice. Summaries of our primary energy

consumption projections for the Asia-Pacific region and the newly independent states (NIS, the countries of the former Soviet Union) are shown in Tables 5.1 and 5.2, respectively. The associated emissions of CO_2—the major fossil energy related greenhouse gas—are shown in Tables 5.3 and 5.4, respectively. These projections reveal several striking differences between the two regions. The first is that while fossil fuel use in the Asia-Pacific region is expected to increase by 90 percent, from 88 billion gigajoules (GJ) in 1993 to 167 billion GJ in 2010, NIS fossil energy use is expected to increase only slightly, from 58 billion GJ in 1993 to 70 billion GJ in 2010, or about 21 percent. In addition, while the fuel mix in

Table 5.1 Asia-Pacific energy consumption by fuel source, 1993, with projections to 2010 (billion gigajoules)

Energy source	1993	2000	2010
Gas	6.67	10.00	17.42
Oil	31.76	42.76	57.37
Coal	49.52	66.51	91.74
Subtotal fossil	87.95	119.27	166.53
Subtotal nonfossil	2.68	4.09	44.37
Total	90.63	123.36	210.90

Note: Nonfossil energy sources are hydropower, nuclear power, and other renewables.

Table 5.2 Energy consumption in the newly independent states by fossil fuel, 1993, with projections to 2010 (billion gigajoules)

Fossil fuel	1993	2000	2010
Gas	22.95	27.03	32.67
Oil	19.33	14.33	16.36
Coal	16.15	18.52	20.66
Total	58.43	59.88	69.69

Table 5.3 CO_2 emissions in the Asia-Pacific region, 1993, with projections to 2010 (million tonnes of carbon)

Fossil fuel	1993	2000	2010
Gas	93	139	242
Oil	632	851	1,142
Coal	1,228	1,649	2,275
Total	1,953	2,639	3,659

Table 5.4 CO_2 emissions in the newly independent states, 1993, with projections to 2010 (million tonnes of carbon)

Fossil fuel	1993	2000	2010
Gas	319	376	454
Oil	385	285	326
Coal	401	459	512
Total	1,104	1,120	1,292

Note: Rounding errors occur.

the NIS is expected to remain more or less constant, the mix in the Asia-Pacific region is expected to change appreciably.

These differences can also be seen in the projections of associated CO_2 emissions. In the NIS (Figure 5.1), the projected 21 percent increase in fossil energy use implies a 17 percent increase in CO_2 emissions, from 1,104 million tonnes in 1993 to 1,292 million tonnes in 2010. As explained in

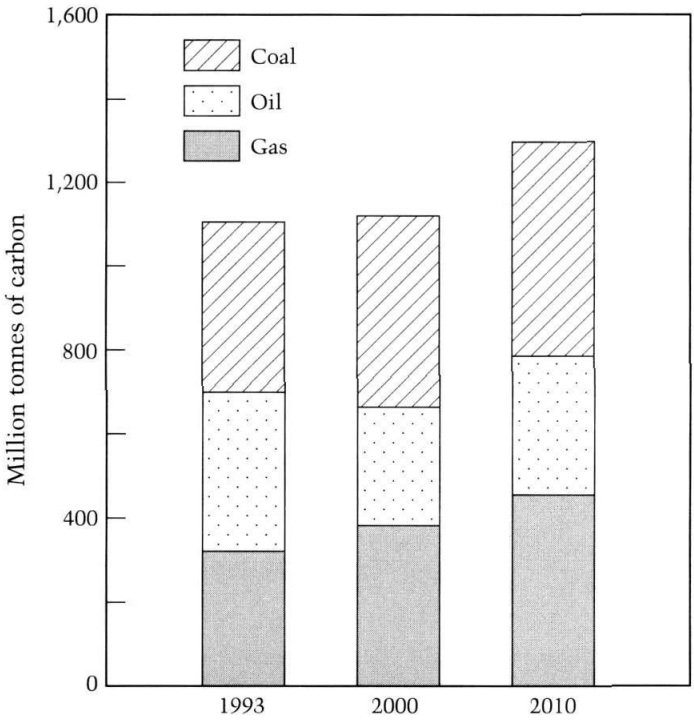


Figure 5.1 CO_2 emissions in the newly independent states, 1993, with projections to 2010

chapters 2 and 4, projections of total NIS energy consumption for the outlook period are not available. In 1993 nonfossil sources accounted for nearly 7 percent of total NIS energy consumption, and this share will probably decline during the outlook period because of heavy investment costs and public opposition that will dampen the development of hydro and nuclear generation. Most of the growth in NIS energy consumption will therefore come from the fossil fuels outlined in Table 5.2.

Asia-Pacific CO_2 emission levels are projected in Figure 5.2, which shows that a 133 percent increase in total energy consumption implies a CO_2 increase of only 87 percent, from 1,953 million tonnes in 1993 to 3,659 million tonnes in 2010. The reason why the percentage increase in Asia-Pacific CO_2 emissions is proportionately so much smaller than the percentage increase in energy consumption is shown in Table 5.2. The nonfossil share of Asia-Pacific energy consumption in 1993 was only 3 percent, but it is projected at about 21 percent in 2010. In these calculations, the nonfossil category consists of the hydro, nuclear, geo-

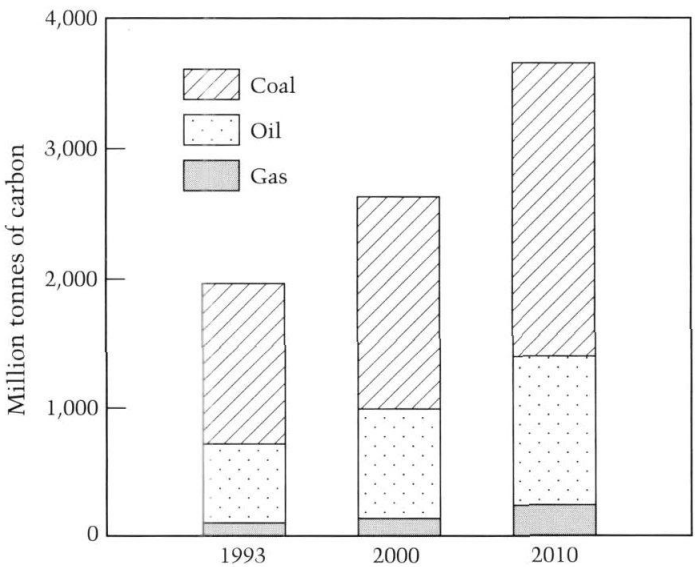


Figure 5.2 CO_2 emissions in the Asia-Pacific region, 1993, with projections to 2010

thermal, and other renewable energy sources outlined in Table 3.13. The largest share of the nonfossil increase in the Asia-Pacific region will come from hydro generation, which is expected to increase by 753 TWh (or about 182%), followed by nuclear generation, which is expected to increase by 632 TWh (or 197%). For comparative purposes, it is interesting to note that a recent U.S. Department of Energy projection estimates that global CO_2 emissions will increase during our outlook period by only 28 percent, from 6,275 million tonnes in 1993 to 8,037 million tonnes in 2010. Thus, the Asia-Pacific region's share of global fossil related emissions, as estimated in Table 5.3, would change from 31 percent in 1993 to about 46 percent in 2010.

In the Asia-Pacific region, the effect of the 21 percent increase in nonfossil power sector generation is even more pronounced when the growth of power generation is compared with the growth of CO_2 emissions from the power sector. Table 5.5 (which is based on the electricity generation projections shown in Table 3.13) and Figure 5.3 project an increase in CO_2 emissions of about 118 percent, from 481 million tonnes of carbon in 1993 to 1,048 million tonnes in 2010. During the same period, however, electricity generation is expected to increase by 162 percent, from 2,669 TWh to 6,958 TWh. By 2010, therefore, without the changes in generation mix (i.e., the increased use of nonfossil generating sources) projected by the region's utilities, CO_2 emissions from the Asia-Pacific power sector could increase by an additional 44 percent, to match the expected growth of electricity generation. As indicated in chapter 3, however, some of

Table 5.5 CO_2 emissions in the Asia-Pacific power sector, 1993, with projections to 2010 (million tonnes of carbon)

Fossil fuel	1993	2000	2010
Gas	52	77	127
Oil	94	70	60
Coal	335	561	861
Total	481	707	1,048

Note: Rounding errors occur.

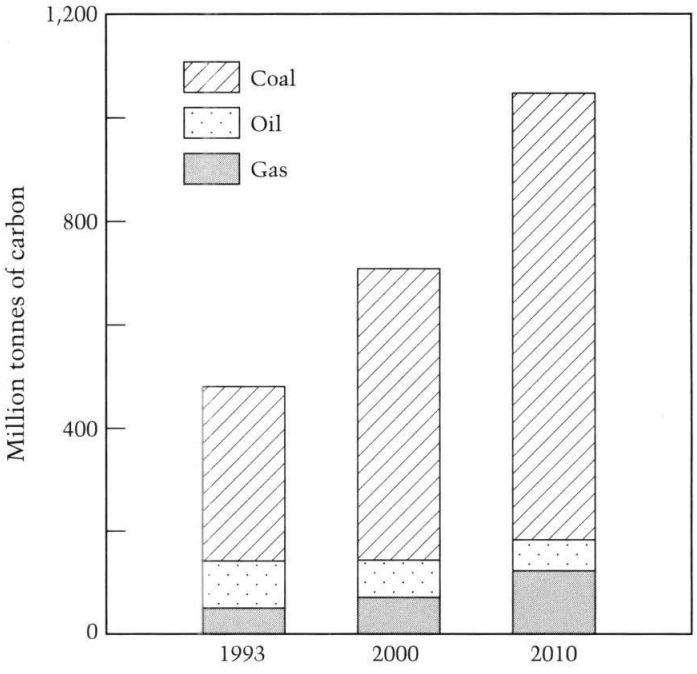


Figure 5.3 CO_2 emissions in the Asia-Pacific power sector, 1993, with projections to 2010

the ambitious nuclear and hydro generation projects will not materialize. As utilities deal with their shortfalls by using more fossil fuels, CO_2 emissions will in fact increase above the levels implied by current official plans.

From the projections provided here, it is clear that the technology choices made now and in the near future will have a major effect on the environment. It is also clear that the countries in the region would like to expand the use of renewable energy (primarily hydro) and nuclear power for power generation. However, when discussing the environmental impacts of energy development and use, it is important to remember that all major energy developments affect the environment. Fossil based systems give rise to air emissions associated with issues such as climate change. Hydro facilities can have large land use impacts and displace thousands of people. And nuclear facilities face public opposition associated with operational safety and waste disposal. Thus,

in examining the environmental effects of energy development in the Asia-Pacific region, the choice is not whether there will be significant impacts on the environment, but how to choose technologies that will minimize environmental impacts in a cost effective manner.