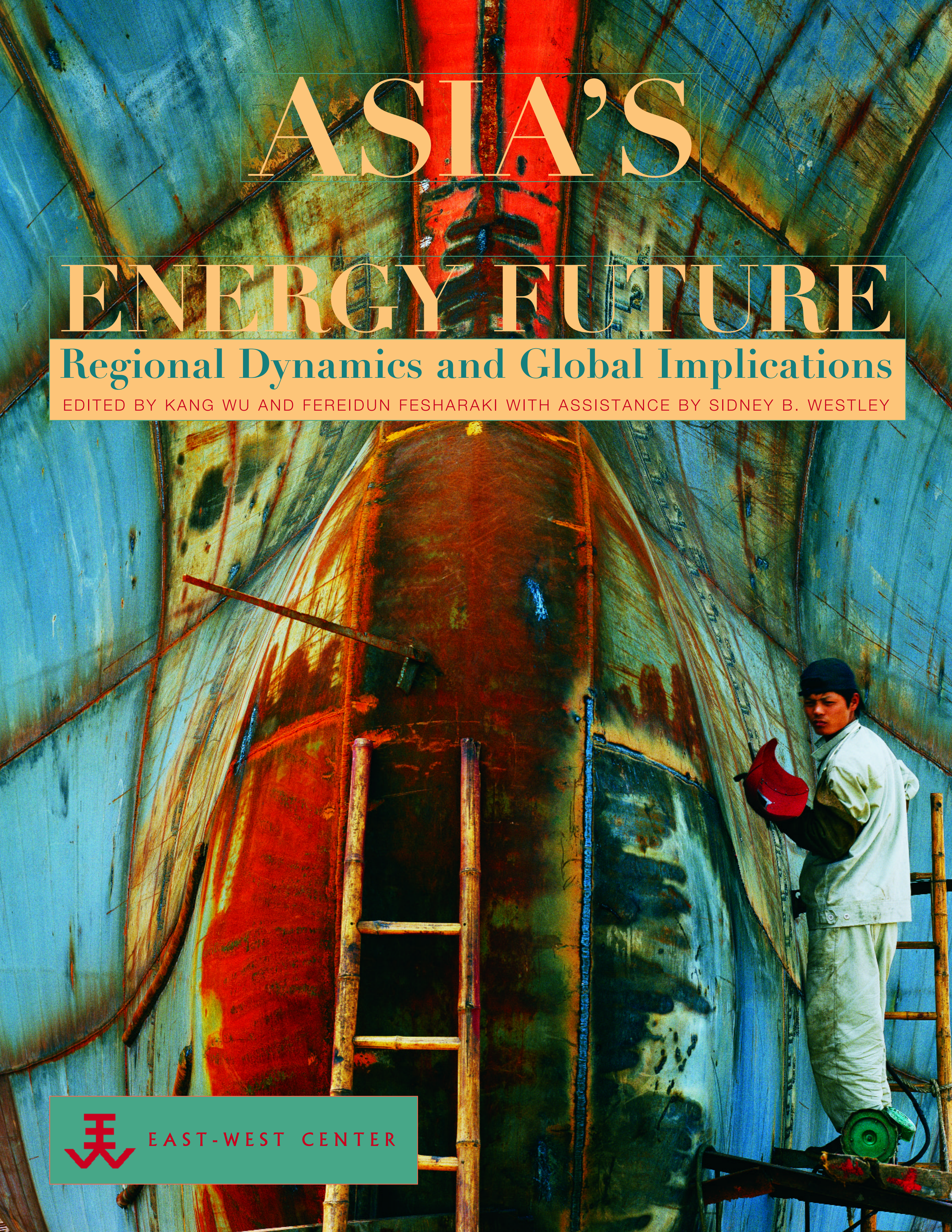

ASIA'S ENERGY FUTURE

Regional Dynamics and Global Implications

EDITED BY KANG WU AND FEREIDUN FESHARAKI WITH ASSISTANCE BY SIDNEY B. WESTLEY

EAST-WEST CENTER

BELOW

Three Gorges Dam on the Yangtze River in China. When completed, this will be the largest hydroelectric power project in the world. © Edward Burtynsky, courtesy Robert Koch Gallery, San Francisco, and Charles Cowles Gallery, New York

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Designed and produced by Barbara Pope Book Design
Printed in Hong Kong by Everbest Printing Company

E-ISBN: 978-0-86638-213-7
PRINT ISBN: 978-0-86638-212-0

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Preface

Construction worker cuts steel tubing for an offshore oil-drilling platform in Batam, Indonesia. Although a member of the Organization of the Petroleum Exporting Countries (OPEC), Indonesia consumes more oil than it produces. © Robert Garvey/Corbis

Energy security ranks as one of the highest-priority issues in Asia and the Pacific. The East and South Asia region is the fastest-growing oil consumer in the world, and because this region has such a small percentage of the world's oil reserves, it is the most highly dependent on oil imports of any world region. In the future, Asia will become even more dependent on imports as its energy needs expand with changing life styles and overall economic growth.

Asia's increasing energy needs have important implications for energy security throughout the world, and particularly in the United States. Like Asia, the United States is a large and growing importer of crude oil and petroleum products. It is also becoming a direct competitor with the East Asian economies for imported liquefied natural gas (LNG).

This volume is intended to provide Asians and Americans with the factual information they need for clear understanding, informed policy dialogue, and effective cooperation on issues related to energy security. The United States and Asia have much in common in terms of their basic energy situation. Both regions have enormous hydrocarbon reserves in the form of coal, but both must import huge quantities of liquid hydrocarbons in the forms of oil and natural gas. The United States has an economy and a life style highly dependent upon imported energy, and increasingly, so does Asia. The environmental implications of energy use are of growing concern in both regions. Both share a common stake in an assured supply of oil and natural gas, in price stability in international energy markets, in efficient and sustainable use of oil and gas products, and in the development of technologies and fuel alternatives that can alleviate energy security and environmental concerns.

Two editors of this volume, Fereidun Fesharaki and Kang Wu, are leading international energy experts based at the East-West Center. They have assembled an outstanding team of Asia-Pacific specialists to describe recent trends and future challenges and to lay out a set of policy recommendations designed to strengthen the region's overall energy security. We at the East-West Center hope that this book will make a strong contribution toward understanding Asia-Pacific energy issues and solving the region's common energy problems.

Charles E. Morrison
President, East-West Center

Rush hour in Kolkata (formerly Calcutta), India. Between 1990 and 2000, the number of motor vehicles per capita more than doubled in four Asia-Pacific nations: South Korea, the Philippines, India, and China.
© Arindam Mukherjee/Landov

Foreword

Fereidun Fesharaki

Concerns about energy security affect economic performance and political stability all over the world. Yet nowhere is the issue more critical than in Asia and the Pacific. In particular, rising fuel consumption to support the region's rapid economic growth has led to a worrying degree of dependence on oil imports from the Middle East.

As of 2005, Asia and the Pacific accounted for 30 percent of the world's total oil consumption but only 10 percent of global oil production (see Figure 1.10). The importance of the region is reflected not so much in its share of total consumption, however, as in its share of consumption growth. Since 1990, well over one-half of the annual growth in global oil consumption has originated from Asia and the Pacific (Table F.1). In 2004, China alone accounted for nearly one-third of the growth in oil consumption in the entire world. This rapid growth in consumption has increased imports into the region dramatically, contributing to price volatility on the global market. Coupled with emerging supply limitations, the Asia-Pacific region's increasing demand for oil raises fears of tensions among Asian nations and between Asia and the West.

Natural-gas consumption is relatively modest in Asia and the Pacific. In 2005, the region accounted for only 14 percent of the world's total consumption. The Asia-Pacific region produces more than 90 percent of the natural gas it consumes, but a trend toward rapidly increasing consumption will lead to a greater dependence on imports and will also contribute to the globalization of gas markets. Expanding trade in natural gas—both across the region and at the global level—will require enormous capital investments and elaborate networks of international agreements.

Apart from the region's role in global oil and natural-gas markets, energy consumption in Asia and the Pacific has a large and growing effect on the global environment. Coal is widely used in the region for electricity generation, domestic heating, and manufacturing. Given the level of technology currently in use, coal combustion tends to produce harmful air pollution, with effects on human health and global climate change. Several Asia-Pacific countries also use nuclear power, primarily to generate electricity. Safety and environmental issues are growing concerns.

The global oil market

The years 2004 and 2005 brought several firsts to the global oil market. In 2004, consumption grew at the fastest rate observed over the previous 25 years. Oil

Table F.1. Annual growth in oil consumption in the Asia-Pacific region and the rest of the world, 1990–2005 (thousand barrels per day)

	Thousand barrels per day		
Year	Asia-Pacific	Rest of world	Total
1990	716	–386	330
1991	620	–210	410
1992	907	–347	560
1993	753	–423	330
1994	914	–74	840
1995	938	462	1,400
1996	867	763	1,630
1997	783	717	1,500
1998	–182	602	420
1999	982	638	1,620
2000	491	189	680
2001	65	625	690
2002	267	363	630
2003	817	733	1,550
2004	1,073	2,107	3,180
2005	445	605	1,050
Total	10,456	6,364	16,820

Sources: OECD/IEA (2006); FACTS Global Energy (2006).

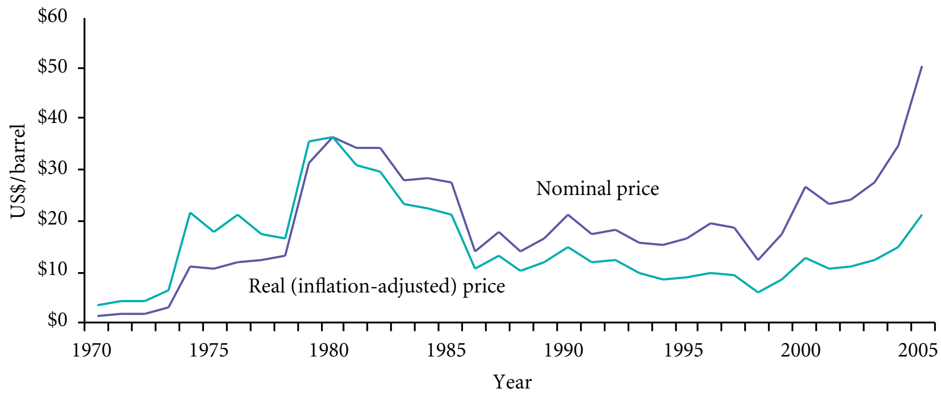
prices in the United States reached an average of more than US$40 per barrel in 2004 and more than US$55 per barrel in 2005—the highest nominal prices in history. During 2004, oil consumption in China increased by some 800,000 barrels per day (b/d), compared with an average increase of just over 300,000 b/d between 2000 and 2003. This was the fastest annual growth in oil consumption ever recorded in any country. The high nominal price of oil did not seem to have any significant impact on consumption growth.

In 2005, by contrast, the growth of world demand for oil slowed down considerably, partially because of high prices. In China in particular, the annual increase in oil consumption fell below 300,000 b/d.

Oil price estimates in the United States are based on the price of West Texas Intermediate (WTI) crude oil traded in the New York Mercantile Exchange (NYMEX). In Asia and the Pacific, however, oil prices are based on Dubai crude, which remained at an average of US$34 per barrel during 2004 but soared to US$61 per barrel in 2006. In the Asia-Pacific market, the real price (adjusted for inflation) was far below the peak reached in 1979 (Figure F.1).

In the late summer of 2005, oil prices marked another historic record. The WTI price went above US$70 per barrel, and the Dubai price went above

Figure F.1. Trend in price of Arab light crude oil, 1970–2005: Nominal and real (inflation-adjusted) 1980 prices (U.S. dollars per barrel)



Source: FACTS Global Energy (2006).

US$60 per barrel. Natural-gas prices were also at an all-time high. In 2006, oil prices continued to be high, while natural-gas prices in the United States began falling off at the end of the 2005 hurricane season.

In real terms, the price of Dubai crude is projected to reach about US$80 per barrel by 2014 according to the East-West Center's base-case scenario. Price projections for 2015 range from more than US$100 per barrel (high scenario) to US$50 per barrel (low scenario), but not lower. The base-case price will still be lower in real terms (adjusted for inflation) than the 1979 peak.

In the short term, global oil prices might decline temporarily as demand slows down and inventory builds up (Figure F.2). Higher prices have triggered some degree of conservation, and the unprecedented growth of oil consumption in 2004 slowed down in 2005 and 2006. A deliberate effort by the Chinese government, coupled with a slowdown in the U.S. economy, has reduced the global increase in oil consumption to 1.1 million b/d in 2005 and 1.0 million b/d in 2006, compared with an increase of more than 3 million b/d in 2004. But despite the slowdown in consumption growth, there is a fundamental floor below which prices are unlikely to fall.

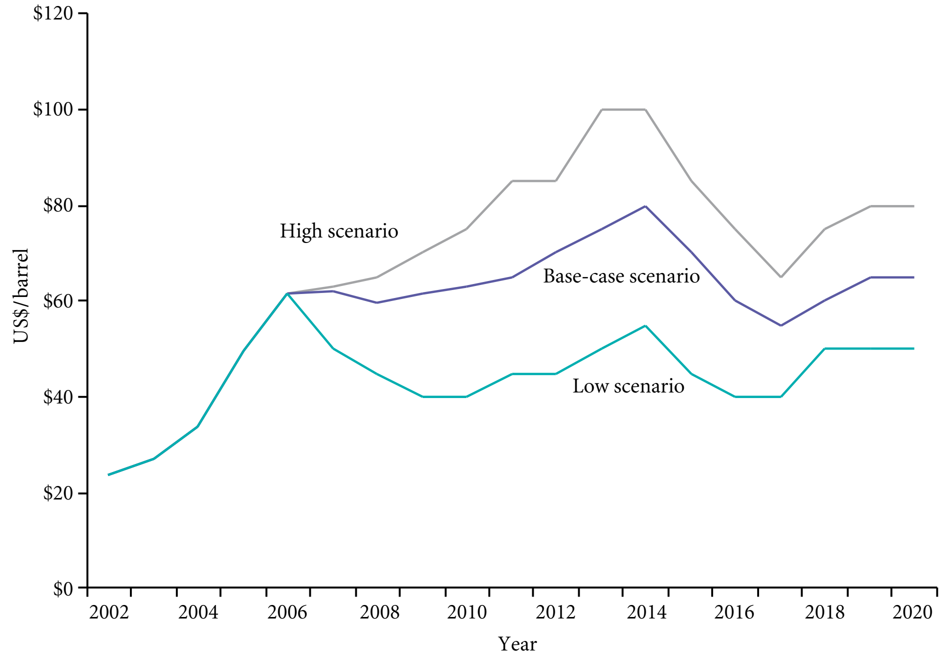
Our base-case projection is that the price of Dubai crude will go down slightly in 2007, return to its current level some time in 2008, and rise steadily after that. The trend toward higher oil prices is based on fundamentals of supply and demand and must be considered long term. Toward the end of the current decade, prices are likely to be higher, not lower, under our scenario.

The global market for natural gas

World consumption of natural gas is growing even more quickly than consumption of oil. Between 2000 and 2025, global natural-gas consumption is projected to increase by 72 percent, significantly faster than growth in consumption of any other energy source.

As of early 2005, natural-gas prices were at an all-time high, led by the market

Figure F.2. Actual and projected prices of Dubai crude oil using low, base-case, and high forecast scenarios, 2002–2020 (U.S. dollars per barrel)



Source: FACTS Global Energy (2006).
Note: Data for 2002–2006 are actual; data for 2007–2015 are forecasts based on 2007 U.S. dollars.

in the United States. After decades of prices staying in the range of US$2 per million British thermal units (mm Btu), natural-gas prices in the United States reached US$7–8/mm Btu in late 2004, a nearly fourfold increase. By late summer 2005, prices were in the range of US$10/mm Btu. Comparing annual averages, the price of natural gas at Henry Hub (a natural-gas pipeline hub in Louisiana) went up from US$1.9/mm Btu in 1995 to US$4.2/mm Btu in 2000, US$5.9/mm Btu in 2004, and US$8.8/mm Btu in 2005—more than a fourfold increase in 10 years. While natural-gas prices have since come down somewhat, we believe that in the longer term prices will be in the range of US$6–7 per mm Btu.

How does this compare with the cost of oil? Natural-gas prices of US$7–8/mm Btu correspond to WTI prices of well over US$45–50 per barrel. Thus the relationship has changed: Natural gas used to be much cheaper than oil, but in the future, the costs of these two energy sources will be closer. This will be true even though competition from coal tends to hold the cost of natural gas down. This change in the relative prices of oil and natural gas is comprehensive and supported by fundamentals in both the oil and gas markets.

There is a clear trend toward globalization of the market for natural gas, with prices shifting upward in line with global oil prices. Because the United States is the world's largest consumer of natural gas, the global gas market will be dominated by futures prices in the United States. Indeed already, the wholesale price at Henry Hub serves as a benchmark spot price (as a floor) for liquefied natural gas (LNG) no matter where the gas originated or where it is sold.

The future of oil production

The global oil market today is driven more by supply than demand. Consumption is affected by economic conditions, prices (including taxes), and regulatory controls. But given current price levels and the current state of technology, we are simply reaching a limit on our capacity to produce oil, and this is the most important factor affecting the market.

Of course the issue is not quite so simple. In the world as a whole, proven reserves—the oil supplies that could be extracted, refined, and delivered to customers using current technology—are estimated at 1.2 trillion barrels (BP 2006). With the technical innovations in oil exploration and extraction already envisaged, total reserves may increase, but we are approaching the technical limits, which are defined by natural declines in oil production and smaller discoveries of new sources. Global oil production, which now stands at about 85 million b/d, might increase to 100 or perhaps even 105 million b/d, but it cannot go up indefinitely.

The problem is that three-quarters of the world's proven oil reserves are owned by members of the Organization of the Petroleum Exporting Countries (OPEC). And the OPEC countries are not willing—or able—to change their policies to encourage higher production to keep up with global demand. OPEC members are Algeria, Angola, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates (Abu Dhabi and Dubai), and Venezuela. Among these, only Saudi Arabia has excess production capacity today, and this excess capacity is limited.

In fact, OPEC oil producers experienced a natural decline in production of 1.2 million b/d in 2005, and this natural decline is projected to deepen in the near future. This means that OPEC producers must increase production capacity by 6 million b/d over the next five years just to keep production at current levels. For key OPEC nations, the problem with increasing—or even maintaining—production levels is not a resource constraint, but rather a policy constraint.

Constraints in OPEC countries shift the emphasis to the one-quarter of global oil reserves owned by non-OPEC members. The main non-OPEC oil producers are the United States, China, the United Kingdom, Mexico, Russia, and countries in Central Asia. Over the past 10 years, oil production from non-OPEC countries has grown at an annual rate of more than 1.5 million b/d. This growth rate is projected to slow down, however. Over the next five years, annual increases in oil production from non-OPEC countries are likely to decrease to half the previous rate, and production is likely to peak in the early part of the next decade. While production in Russia and Central Asia will rise, this will be offset by declines in the North Sea and other regions. This means that rapidly growing oil consumption in the Asia-Pacific region and elsewhere in the world will have to be supplied by OPEC.

Natural-gas production platform in the Gulf of Thailand. Expanding the use of natural gas offers one option for reducing dependence on imported oil. © Hanan Isachar/ Corbis

Apart from questions of politics and legal restrictions, the amount of oil actually available from OPEC member countries, particularly the major ones in the Middle East—Saudi Arabia, Iran, Iraq, Kuwait, and the United Arab Emirates—is frequently debated. Some observers claim that reserves in the Middle East are overstated and there will be a collapse in production, leading to a drop of oil production globally. Others argue that oil supplies in the Middle East and other parts of the world will grow indefinitely. The truth lies somewhere between these two extremes.

Estimates of Middle-Eastern oil reserves are not certified, and some are very likely overstated. There will be no collapse in production, however, and with application of new technologies, it should be possible to recover, refine, and market most of the oil claimed to be in the region's reserves. But we cannot expect production to continue increasing as it has in the past. Somewhere between about 2015 and 2020, global oil production may reach its peak, limited either by the resources available or the policies of oil-producing nations.

The American oil and gas markets

The United States is by far the largest consumer of oil and natural gas in the world. All of Europe combined uses less oil and gas than the United States. China—with a population four times larger—uses less than one-third of the oil consumed in the United States. Japan, the largest importer and consumer of LNG in the world, uses only one-seventh as much natural gas as the United States.

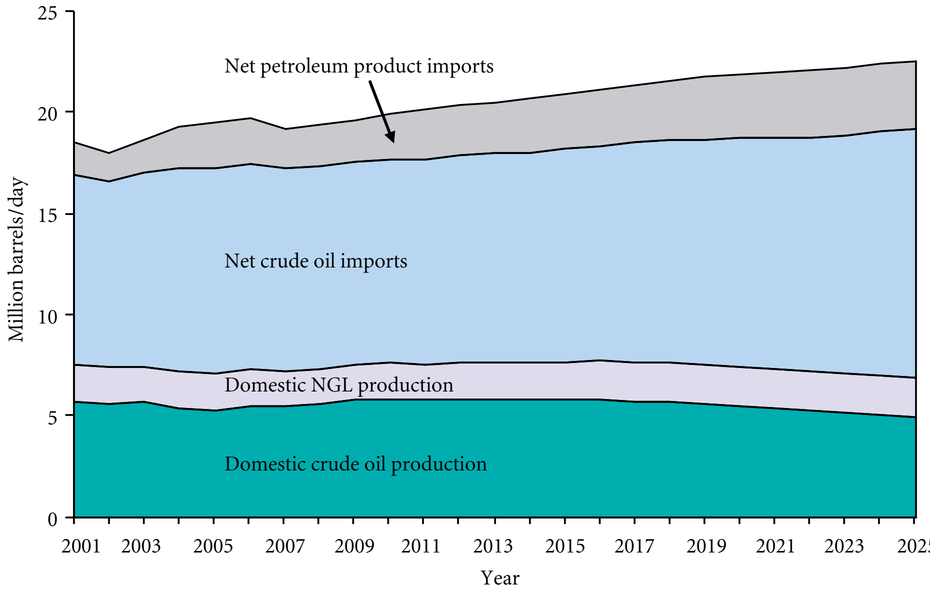
In addition to being the largest oil consumer, the United States (along with China) has accounted for most of the global growth in oil consumption in recent years. And while consumption has been growing, domestic production in the United States has been shrinking, resulting, inevitably, in an increasing dependence on imported oil (EIA 2006) (Figure F.3).

This trend will continue. In 2005, the United States consumed an estimated 20 million b/d of oil but produced only 8 million b/d, leaving a shortfall of 12 million b/d to be filled by imports of crude oil and petroleum products. By 2025, the projections are for 27 million b/d of consumption, compared with only 7 million b/d of production, leaving a shortfall of 20 million b/d.

The United States is also reaching the limit of its refining capacity. Although some existing refineries are being expanded, stringent environmental regulations impede the construction of new refineries. This means that imports of refined petroleum products are increasing more quickly than imports of crude oil. In 2005, an estimated 15 percent of all U.S. oil imports were in the form of refined petroleum products. In 2025, refined products will account for an estimated 20 percent of oil imports.

The same high environmental standards also impose tight quality restrictions on the choice of petroleum products that may be imported. Given these constraints, the American market is finely balanced. Any problem—such as

Figure F.3. Projected trend in production and imports of crude oil and petroleum products in the United States, 2001–2025 (million barrels per day)



Source: EIA (2006).
Note: NGL is natural-gas liquid, a byproduct of natural-gas production that can be refined into petroleum products. Data for 2001–2005 are actual, data for 2006 are preliminary, and data for 2007–2015 are forecasts.

an accident in a key refinery or a hurricane—can lead to significant supply uncertainty and large price spikes.

Predicting the future

Much of future oil consumption will be closely linked to economic growth, which is notoriously difficult to predict. It is reasonable to project, however, that global demand for oil will grow in the range of 1 to 2 million b/d each year. Will there be enough oil production around the world to supply this demand? The answer is "no."

Today, OPEC countries are experiencing an annual natural decline in oil production capacity of about 1.2 million b/d. In the future, small increases are plausible, but a big capacity increase outside of Iraq is unlikely. Production in non-OPEC countries will peak in the next few years and then start to decline. Thus, at some time in the next decade, global oil production will reach a plateau, and today's rapid consumption growth will become unsustainable.

The key agencies responsible for long-term forecasting of oil production and consumption are the Organization for Economic Cooperation and Development's International Energy Agency (OECD/IEA), which represents 26 industrialized nations, and the Energy Information Administration (EIA) of the United States Department of Energy. The OECD/IEA (2005) predicts very large growth in oil consumption, while the EIA has recently revised its long-term forecast substantially downward. According to the EIA's most recent forecast (EIA 2006), global oil consumption will rise from 84 million b/d in 2005 to 111 million b/d in 2025, which is 8 million b/d lower than the forecast made in 2005 (EIA 2005). The 2006 EIA forecast assumes that imported crude oil will cost $48 per barrel by 2025, significantly higher than the $35 per barrel assumed in 2005.

Both the OECD/IEA and the EIA forecast very large increases in oil production from OPEC members, but this does not mean that such production will actually be forthcoming. The forecasts show only that OPEC production must reach a certain level to balance the level of consumption that is projected.

The only alternative is for oil consumption to stop growing. This can happen as a result of higher prices, economic recession, taxation, or other regulatory mechanisms. It may also happen as a result of technological breakthroughs that allow switching to other energy sources.

The world has used oil for more than a century without paying serious attention to future availability. In many countries today, environmental regulations have complicated the production, refining, and transport of oil. In the United States, for example, some 100 different grades of gasoline and diesel fuel are required in specific localities. At the same time, investment in new production and refining capacity has been limited.

What does all this mean? In the absence of any other factors to reduce demand, high prices are inevitable. Higher prices will lead to lower demand, but prices may have to reach US$100 per barrel before demand slows down. Lower demand may eventually nudge prices downward, but the price of oil is not likely to drop below US$55–65 per barrel.

High prices for energy impose a strong brake on economic growth. For countries in Asia and the Pacific that expected to follow the pattern of energy-intensive growth seen in the West, the challenge ahead is daunting. They need energy, they need low prices, but they have arrived at the development gate at an inauspicious time. They will need to devise new strategies for economic growth based on more efficient use of oil and natural gas, continuing or even increasing dependence on domestic supplies of coal, and ultimately turning, at least in part, to alternative sources of energy.

CHAPTER ONE

The Asia-Pacific Energy Dilemma

Kang Wu

Jeffrey G. Brown

Toufiq A. Siddiqi

Traffic near the cooling towers of a nuclear power plant in Baotou, Nei Mongol Autonomous Region, China. Between 2005 and 2015, China's primary commercial energy consumption, which includes oil, natural gas, coal, nuclear power, and hydropower, is projected to increase by 5 percent a year. © Michael S. Yamashita/Corbis

The Asia-Pacific region plays a critical role in today's global energy markets. Asian and Pacific countries are large and growing consumers of oil and increasingly important consumers of natural gas. As major importers from the Middle East and other regions, their participation in global oil and gas markets affects the availability and cost of energy everywhere in the world. And their growing dependence on imports is at the heart of concerns about energy security in the region.

In addition to oil and natural gas, coal is a particularly important energy source in China, India, the Democratic People's Republic of Korea (North Korea), and other countries of the region. Given the low levels of technology currently in use, heavy dependence on coal in some Asia-Pacific countries raises concerns about harmful air pollution and global warming.

Regional information presented in this book is largely based on data from 44 countries and economies. Information on individual countries and economies focuses on the major energy producers and consumers in the region: Bangladesh, India, Nepal, Pakistan, and Sri Lanka in South Asia; Brunei Darussalam, Indonesia, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam in Southeast Asia; China, North Korea, Hong Kong Special Administrative Region (SAR), Japan, the Republic of Korea (South Korea), and Taiwan in East Asia; and Australia and New Zealand in the Pacific (Figure 1.1).

Sources of energy include fossil fuels (oil, natural gas, and coal), traditional biomass fuels (trees, shrubs, and agricultural and animal wastes), renewable energy sources (hydropower, solar, geothermal, and wind), and nuclear power. Several countries in the region—including China, India, Bangladesh, Pakistan, Indonesia, and Vietnam—still make considerable use of traditional biomass sources of energy. It is difficult, however, to estimate total energy use in situations where fuel is not traded in the marketplace. For this reason, the discussion focuses mainly on primary commercial energy, which is defined to include oil, natural gas, coal, nuclear power, and hydropower. Traditional biomass fuels, as well as geothermal, solar, and wind energy, will be included in the discussion where relevant data are available.

Energy consumption: World's fastest growth

Energy consumption is growing more quickly in Asia and the Pacific than in any other region of the world. Between 1965 and 2005, primary commercial energy consumption in the region increased sixfold (Figure 1.2). And the rate

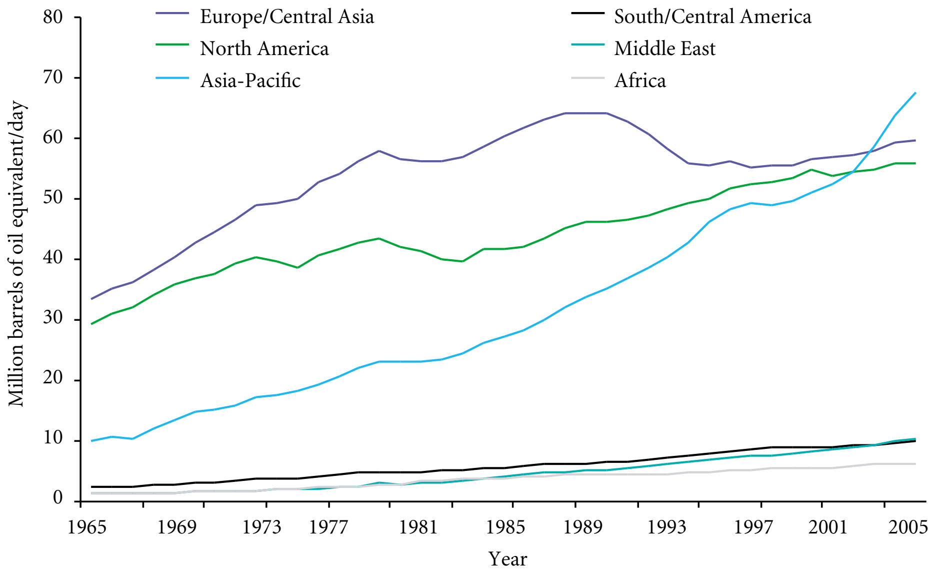
Figure 1.1. Map of the Asia-Pacific region
Source: East-West Center.

Notes: Major energy producers and consumers in the region are: Bangladesh, India, Nepal, Pakistan, and Sri Lanka in South Asia; Brunei Darussalam, Indonesia, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam in Southeast Asia; China, the Democratic People's Republic of Korea (North Korea), Hong Kong Special Administrative Region (SAR), Japan, the Republic of Korea (South Korea), and Taiwan in East Asia; and Australia and New Zealand (not shown) in the Pacific.

Other countries/economies included in regional totals are: Afghanistan and Maldives in South Asia; Cambodia, Timor-Leste, and Lao People's Democratic Republic in Southeast Asia; Macao SAR and Mongolia in East Asia; and the Federated States of Micronesia, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu in the Pacific.

Boundaries represented in the map are not necessarily authoritative.

Figure 1.2. Trends in total annual energy consumption (million barrels of oil equivalent/day) in major regions of the world, 1965–2005



Sources: BP (2006); FACTS Global Energy (2006).
Notes: Primary energy is limited to commercially traded fuels. Excluded are traditional biomass fuels such as wood, peat, and agricultural and animal waste, which, although important in many countries, are unreliably documented in consumption statistics.

of growth is accelerating. In 1995, Asia and the Pacific accounted for 27 percent of global primary commercial energy consumption. By 2005, this share had increased to 32 percent (Appendix Table 1.1). In 2015, the region will account for a projected 38 percent of the world's energy consumption.

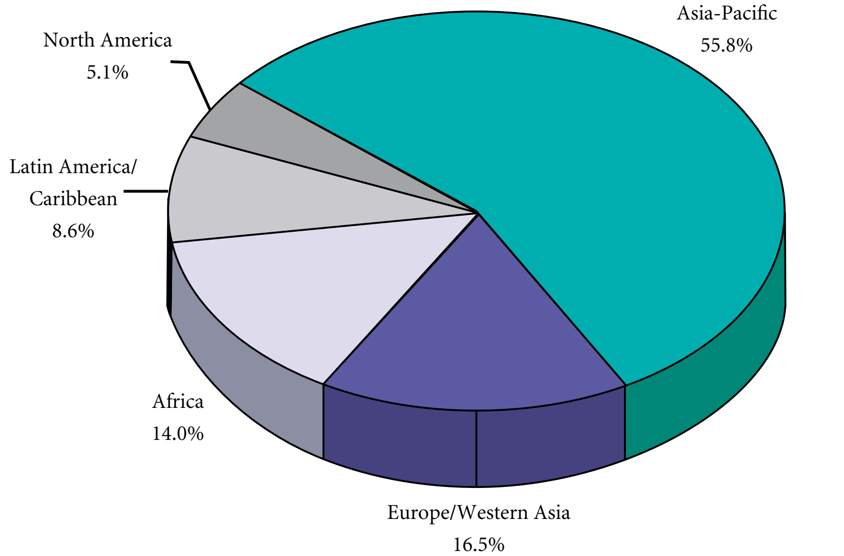
Population alone would suggest that the Asia-Pacific region is an important player in world energy markets. In mid-2005, the region accounted for 56 percent of world population, well over twice the size of any other region (Figure 1.3 and Appendix Table 1.2). Fertility is projected to decline somewhat in Asia and the Pacific, but the region will still account for more than one-half of global population in 2050 (PRB 2005).

Although total energy use is large because of the region's large population, citizens of Asia and the Pacific use relatively little energy per capita (Figure 1.4 and Appendix Table 1.3). On average, 10 people in the Asia-Pacific region use about as much energy as two people in Europe or one person in the United States. This current low use of energy per capita points to enormous potential for consumption growth in the future. Will governments in the region be able to meet the future energy demands of their citizens? And at what cost?

Energy consumption and economic growth. Rapid growth in energy consumption will stem largely from the Asia-Pacific region's unprecedented economic growth. In fact, trends in the region offer a textbook illustration of how economic growth and primary energy consumption usually go hand in hand.

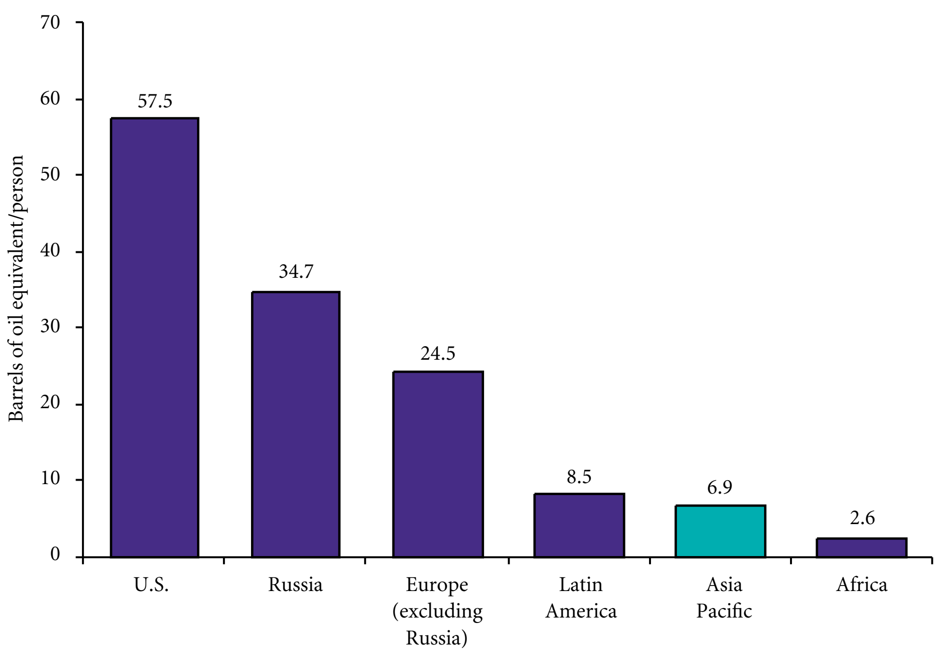
Over a quarter century from 1980 to 2005, annual economic growth in Asia

Figure 1.3. Proportion of total global population in major regions, mid-2005



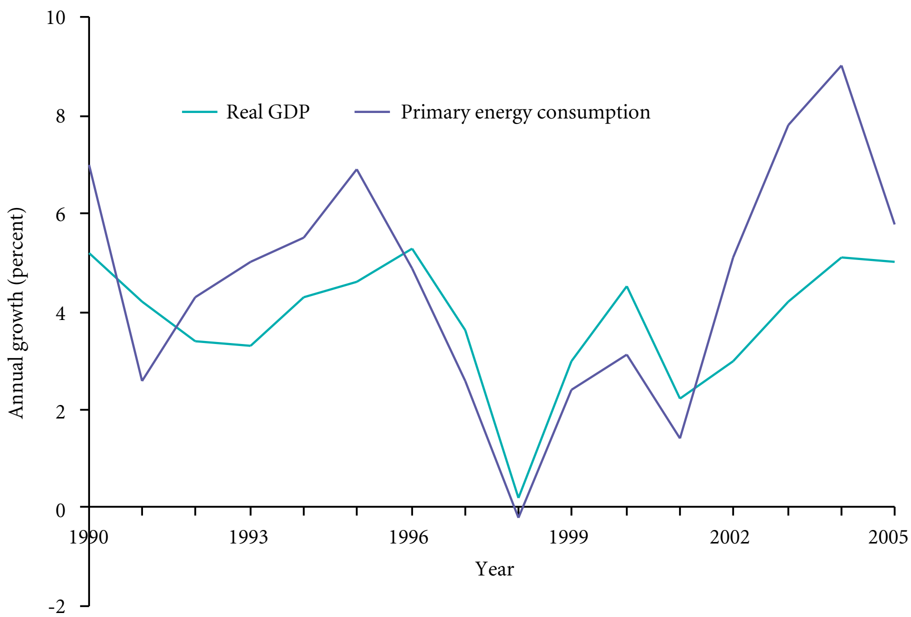
Source: PRB (2005).
Note: Proportions in figure are not exactly the same as in Appendix Table 1.2 due to rounding.

Figure 1.4. Per-capita annual primary commercial energy consumption (barrels of oil equivalent) in the United States, Russia, and major regions of the world, 2005



Sources: BP (2006); PRB (2005); FACTS Global Energy (2006).

Figure 1.5. Primary energy consumption and real gross domestic product (GDP) in the Asia-Pacific region: Annual growth rates 1990–2005



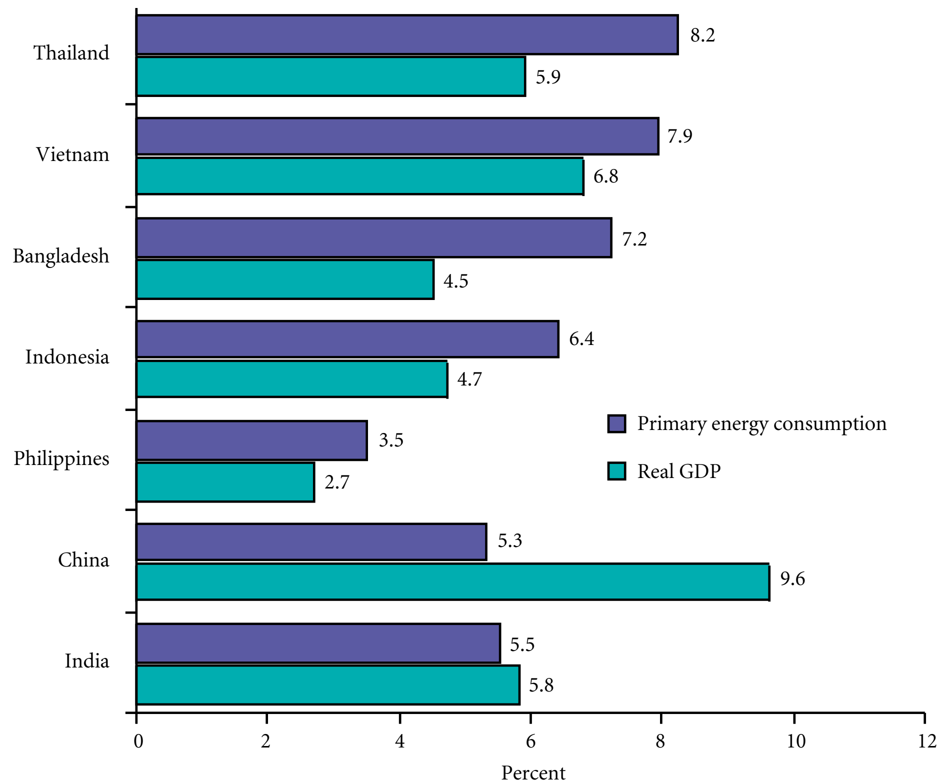
Sources: IMF (2006); BP (2006); OECD/IEA (2006); FACTS Global Energy (2006).

and the Pacific averaged 4.2 percent, while annual growth in primary energy consumption averaged 4.4 percent (Appendix Table 1.4). During the economic boom years of 1990–1996, growth in energy consumption accelerated (Figure 1.5). The economic crisis of 1997–1998 slowed both regional economic growth and growth in energy consumption dramatically, but both recovered and began climbing steeply again.

While the precise relationship between energy consumption and economic growth is a matter of academic debate, rapid economic growth tends to be associated with large increases in energy consumption at early stages of industrialization. Growth rates for energy consumption and real gross domestic product (GDP) in several developing countries of Asia and the Pacific illustrate this link (Figure 1.6 and Appendix Table 1.4). As economies mature, economic growth typically becomes less energy intensive, and the linkage between economic growth and energy consumption weakens.

Two countries at early stages of industrial development stand out as exceptions to this pattern—China and, to a lesser extent, India. Why has growth in energy consumption in these two countries lagged behind economic growth, particularly in China? There could be several possible reasons. First, both economies have experienced some degree of structural change, with light industry and the service sector growing faster than the more energy-intensive heavy industrial sector. Second, the introduction of energy-saving measures and the importation of energy-saving machinery have helped both economies move toward greater energy efficiency. A third reason relates to rising energy prices. A policy shift from substantial energy price subsidies to a more market-oriented approach—

Figure 1.6. Primary energy consumption and real gross domestic product (GDP) in selected developing economies of the Asia-Pacific region: Average annual growth rates, 1980–2005 (percent)



Sources: IMF (2006); BP (2006); OECD/IEA (2006); FACTS Global Energy (2006).

with prices increasingly determined by supply and demand—has helped both China and India reduce excessive energy use.

Despite improvements in efficiency, China and India rank, along with Japan and South Korea, as by far the largest energy consumers in the region. Looking ahead to 2015, China is projected to increase energy consumption by 5 percent a year—from 31.1 million barrels of oil equivalent per day (boe/d) in 2005 to 50.8 million boe/d in 2015 (Appendix Table 1.1). Among other Asian and Pacific countries, Bangladesh, Brunei, Myanmar, Nepal, Pakistan, Sri Lanka, and Vietnam are all expected to increase energy consumption by more than 4 percent a year over the same 10-year period (Appendix Table 1.1). In 2015, China alone will account for a projected 51 percent of total primary energy consumption in the Asia-Pacific region, up from 45 percent in 2005.

Energy sources. Among specific energy sources, the Asia-Pacific region uses more coal than the world as a whole and less natural gas (Figure 1.7). Totals for the region are dominated by China and India, however, and both countries are particularly dependent on coal. Without China and India, the energy mix in the rest of the region is dominated by oil. In fact, the Asia-Pacific region, excluding China and India, is more dependent on oil than the world as a whole.

Between 1995 and 2005, oil consumption in Asia and the Pacific increased

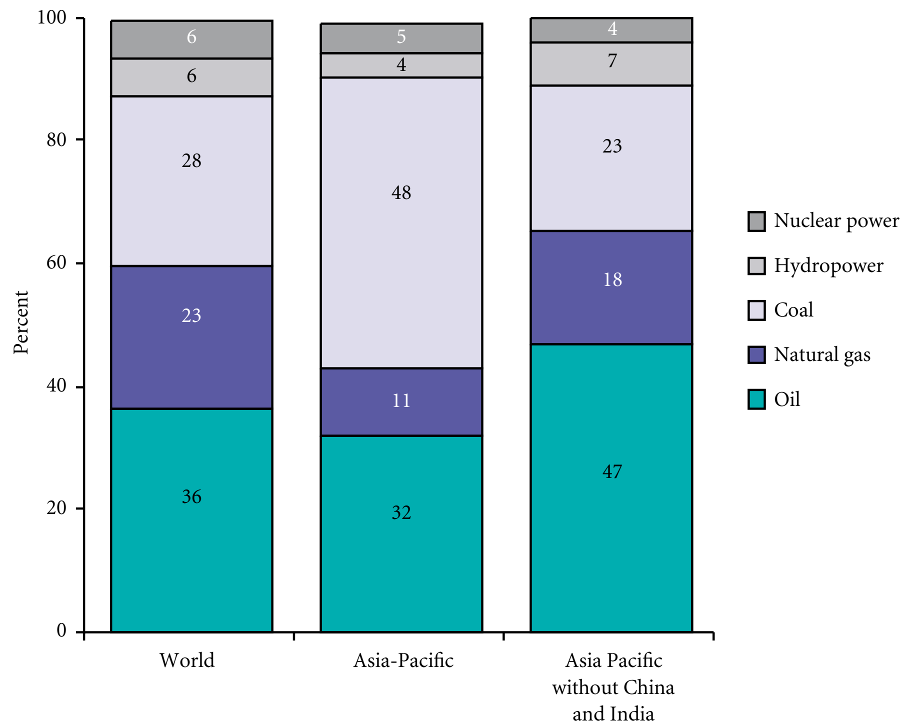
Storage area for oil barrels in Shanghai, China. In 2005, nearly one-half (44 percent) of the oil consumed in China was imported. *© REUTERS/Aly Song/Landov*

It is difficult to compare the amount of energy produced or consumed from different sources because different types of energy are measured in different ways. Crude oil and petroleum products are generally measured in terms of barrels, with one barrel equivalent to about 159 liters or 42 U.S. gallons. Coal is measured in metric tons (tonnes), equal to 1,000 kilograms. Natural gas is measured in terms of volume as cubic meters (m^3) or standard cubic feet (scf) or in terms of heat as British thermal units (Btu). Liquefied natural gas (LNG) is measured in tonnes. Hydropower and nuclear power, used to generate electricity, are measured in watt hours.

All of these energy sources can be compared in terms of barrels of oil equivalent (boe) as a common unit, using the following conversion factors (BP 2006). One boe is approximately equal to:

- Coal: 0.205 tonnes of hard coal or 0.410 tonnes of lignite
- Natural gas: 5,370 standard cubic feet (scf)
- LNG: 0.110 tonnes
- Heat: 5.479 million British thermal units (Btu)
- Electricity: 1.644 megawatt hours. For hydropower and nuclear power, the conversion is based on thermal equivalence assuming 38-percent conversion efficiency in a modern thermal power station

Figure 1.7. Share of oil, natural gas, coal, hydropower, and nuclear power in total primary energy consumption in the world, the Asia-Pacific region, and the Asia-Pacific region without China and India, 2005



Sources: BP (2006); FACTS Global Energy (2006).
Note: Estimates of primary energy consumption include only commercially traded fuels.

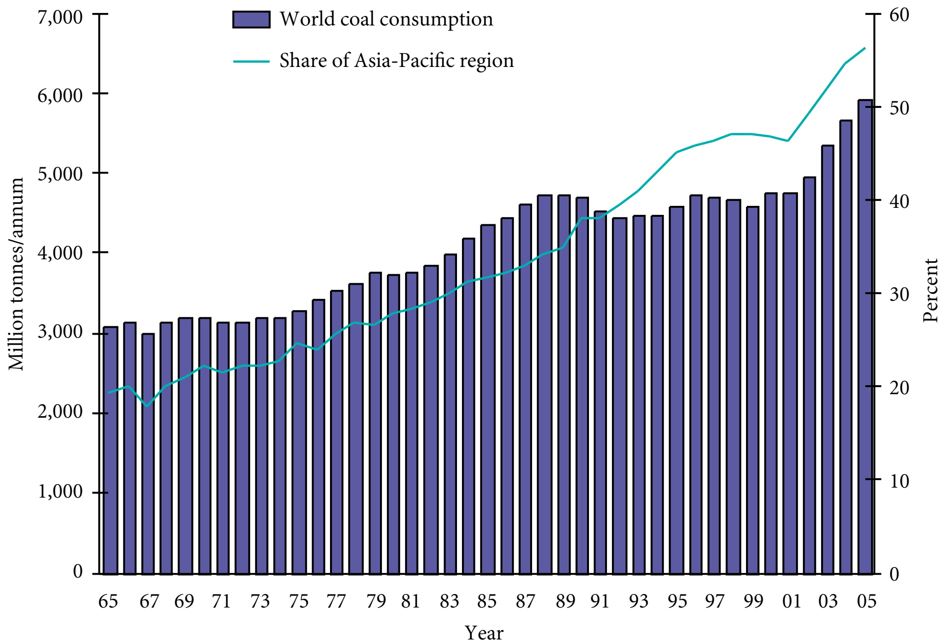
by nearly one-third, or 32 percent (FACTS Global Energy 2006). Over the same 10-year period, global oil consumption also increased, but more slowly—by 18 percent (BP 2006). As a result, the Asia-Pacific region's share in global oil consumption rose from 26 to 29 percent. By 2015, the region will account for a projected 33 percent of global oil consumption.

Among major countries/economies in the region, oil is the most important source of commercial energy consumption in Japan, South Korea, Taiwan, Indonesia, Singapore, Malaysia, Vietnam, Thailand, the Philippines, and New Zealand (Appendix Table 1.5). Although coal is more important than oil in China's overall energy mix, the Chinese use more oil than any other country in the region (Appendix Table 1.1). And oil consumption is growing fastest in China, more than doubling—from 3.2 to 6.5 million barrels per day (b/d)—between 1995 and 2005 (FACTS Global Energy 2006).

Although starting from a much smaller base, natural-gas consumption in Asia and the Pacific is growing even faster than the consumption of oil—increasing by 82 percent between 1995 and 2005 (FACTS Global Energy 2006). Over the same 10 years, world consumption of natural gas went up by only 28 percent (BP 2006). As a result, the region's share in global consumption rose from 10 to 14 percent. Over the next 10 years, natural-gas consumption is projected to continue growing faster in Asia and the Pacific than in the world as a whole.

Natural gas is the most important source of commercial energy in Bangla-

Figure 1.8. World coal consumption (million tonnes per annum) and share of the Asia-Pacific region (percent), 1965–2005



Sources: BP (2006); FACTS Global Energy (2006); OECD/IEA (2006).

desh, Brunei, and Pakistan (Appendix Table 1.5). Japan is the largest consumer of natural gas in the region, however, followed by China, Indonesia, Malaysia, Taiwan, and India (Appendix Table 1.1).

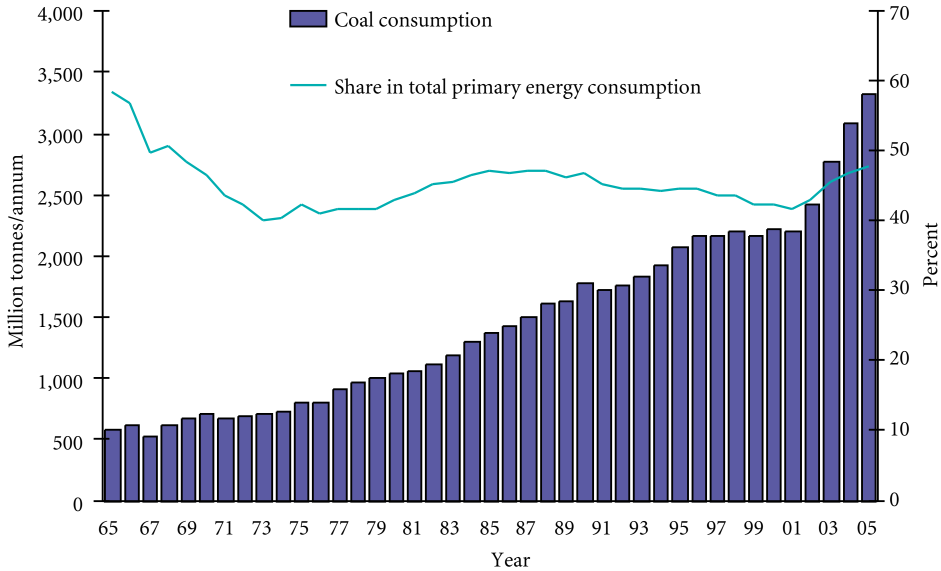
Except for one period of leveling off during the 1990s, world coal consumption has increased steadily over the past 40 years (Figure 1.8). Annual increases in global consumption have been particularly steep since 2000, primarily because of a surge in coal use in China. Within the Asia-Pacific region, coal is the most important energy source in China, India, Australia, and North Korea (Appendix Table 1.5).

Between 1965 and 1995—and, more recently, since 2000—nearly all of the incremental growth in global coal consumption has come from the Asia-Pacific region. As a result, the region's share in global consumption increased from 19 percent in 1965 to a whopping 56 percent in 2005.

While the absolute amount of coal consumed has gone up fairly steadily, the share of coal in regional energy consumption has fluctuated and declined, partly in response to changes in oil prices (Figure 1.9). Persistent increases in international oil prices in 1973–1985 and again since 2001 prompted some degree of fuel switching from oil to coal, mainly for power generation. In 2001, the share of coal in the region's primary commercial energy consumption reached its lowest point, at 42 percent—down from 58 percent in 1965. By 2005, the share had risen again, to 47 percent, mainly because of double-digit growth in coal consumption in China.

In 2005, the Asia-Pacific region generated and used 740 terawatt hours

Figure 1.9. Coal consumption in the Asia-Pacific region (million tonnes per annum) and share of coal in the region's total primary commercial energy consumption (percent), 1965–2005



Sources: BP (2006); FACTS Global Energy (2006); OECD/IEA (2006).
Note: Estimates of primary energy consumption include only commercially traded fuels.

(TWh) of hydroelectric power, equivalent to 3.4 million boe/d (see Appendix Table 1.1). In the region as a whole, hydropower accounted for 5 percent of primary commercial energy consumption (Appendix Table 1.5). China was by far the biggest consumer, using over one-half of the regional total, followed by India and Japan (Appendix Table 1.1).

Despite growing environmental concerns focusing on huge hydroelectricity projects, the use of hydropower is increasing more quickly in Asia and the Pacific than anywhere else in the world. The regional share of the world total grew by five percentage points over 10 years—from 20 percent in 1995 to 25 percent in 2005 (BP 2006). And regional growth of hydropower is expected to continue to outpace the global average in the years ahead. The majority of new hydropower projects in the region will be in China.

In 2005, Asia and the Pacific generated and used 553 TWh of nuclear power, equivalent to 2.5 million boe/d (see Appendix Table 1.1). This was 20 percent of the global total, up slightly from 18 percent in 1995. Only six countries/economies in the region use nuclear power—Japan (consuming more than one-half of the regional total), South Korea, China, Taiwan, India, and Pakistan (Appendix Tables 1.1 and 1.5).

Energy production and resource constraints

Although energy consumption is growing faster in Asia and the Pacific than anywhere else in the world, growth of energy production has been sluggish. Production growth is restricted by the region's limited domestic supplies of oil and natural gas.

Production of specific types of energy varies widely among countries and economies in the region (Appendix Tables 1.6 and 1.7). Natural gas accounts for more than one-half of domestic energy production in Bangladesh, Brunei, Malaysia, Pakistan, and Thailand. Coal accounts for more than one-half of energy production in Australia, China, and India. In Japan, South Korea, and Taiwan, where a large proportion of the energy consumed is supplied by imports, considerably more than one-half of the energy produced domestically is from nuclear power.

No country in the region obtains as much as one-half of its domestic primary energy production from oil, although Brunei, Malaysia, and Vietnam come close. Domestic oil production is constrained by the region's limited reserves. Indeed, Asia and the Pacific have the smallest proven oil reserves of any major region in the world. At the beginning of 2006, the region had an estimated 40 billion barrels of oil reserves, or slightly more than 3 percent of the world total (BP 2006). Within the region, China has by far the largest oil reserves (Appendix Table 1.8), followed by India, Indonesia, Malaysia, and Vietnam.

The internationally accepted definition of proven energy reserves is "those quantities which geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions" (BP 2006). Individual countries may use their own definitions, however. In China, for example, the government and state corporations usually report larger oil, natural-gas, and coal reserves than the levels recognized (or "certified") internationally.

In 2005, Asia and the Pacific produced 7.5 million b/d of oil. Production was by far the highest in China, followed by Indonesia, Malaysia, and India (Appendix Table 1.6). A reserve-to-production (R/P) ratio can be calculated as the oil reserves remaining at the end of 2005 divided by production over the year (Appendix Table 1.8). The result is an estimated number of years that existing reserves can be expected to last if production continues at the same rate and no new reserves are discovered. Given these assumptions, it is estimated that oil reserves in the Asia-Pacific region will last another 14 years—or until 2019.

Predictions of future energy supplies based on reserve-to-production ratios are only indicative, however. As exploration continues, new sources may be identified, and as extraction technologies improve, more oil may be obtained from existing fields. Yet no matter which standards are applied, there is little doubt that today's proven oil reserves in Asia and the Pacific are inadequate to meet the region's current and future energy needs.

The situation is more favorable for natural gas. The Asia-Pacific region has an estimated 8 percent of global natural-gas reserves (BP 2006). In 2005, the region produced 6.0 million boe/d of natural gas, or 12 percent of global production. The largest natural-gas reserves in the region are in Indonesia (Appendix Table 1.8), followed—in order of size—by Australia, Malaysia, and China. The R/P ratio for natural gas is more encouraging than for oil, suggesting that existing natural-gas reserves in the region will last for nearly 41 years if production remains at 2005 levels.

In 2005, Indonesia was the largest producer of natural gas in the region, followed by Malaysia, China, and Australia. China's natural-gas production was geared toward the large domestic market, while Indonesia, Malaysia, Australia, and Brunei were large natural-gas exporters, in the form of liquefied natural gas (LNG).

Coal resources are relatively abundant in Asia and the Pacific. At the beginning of 2006, the region held nearly one-third of the world's estimated 909 billion metric tons (tonnes) of proven coal reserves (Appendix Table 1.8) and accounted for 55 percent of global coal production.

Despite rapidly increasing consumption in recent years, the region as a whole still manages to produce as much coal as it consumes. With ample domestic reserves in many countries, including China and India, R/P ratios suggest that existing coal reserves will last for nearly 100 years, assuming that production continues at 2005 levels. Thus security concerns related to coal focus more on environmental problems than on potential supply limitations.

Growing dependence: The Asia-Pacific energy dilemma

In 2005, the Asia-Pacific region accounted for 33 percent of global energy consumption but only 24 percent of global energy production (Figure 1.10). Combining oil, natural gas, coal, nuclear power, and hydropower, countries in the region consumed 68.2 million boe/d of primary commercial energy but produced only 52.4 million boe/d (Appendix Tables 1.1 and 1.6). The balance of 15.8 million boe/d—nearly one-fourth of total consumption—was filled by imports.

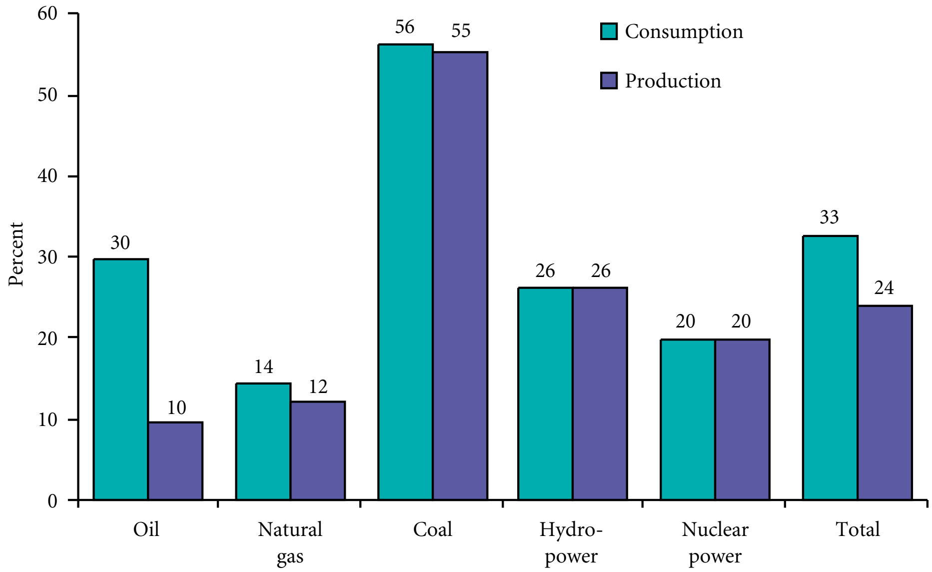
The region as a whole produced almost as much natural gas as it consumed and exported slightly more coal than it imported. Regional consumption of crude oil, however, at 30 percent of the global total, was much larger than the regional share of production, at 10 percent (Figure 1.10).

The result of escalating consumption and stagnating production will be a large and growing dependence on imports, particularly of oil. More than 10 years ago, in the early 1990s, Asia and the Pacific became the largest oil-importing region in the world. With oil consumption projected to increase by nearly one-third between 2005 and 2015 (Appendix Table 1.1), the trend toward greater dependence on imports appears inevitable (see Energy Insecurity Index).

Natural-gas consumption is still relatively low in the region, but it is expected to increase even more quickly than oil consumption, nearly doubling by 2015. Rising natural-gas consumption combined with limited production potential will exacerbate overall dependence on imports from the Middle East.

Because of their dependence on imported oil, many economies in Asia and the Pacific are particularly vulnerable to fluctuations in oil prices. This vulnerability is even greater because regional price formulas for natural gas are often

Figure 1.10. Share of the Asia-Pacific region in global consumption and production of oil, natural gas, coal, hydropower, and nuclear power, 2005 (percent)



Sources: BP (2006); FACTS Global Energy (2006).
Note: Estimates of primary energy consumption and production include only commercially traded fuels.

linked to crude-oil prices. When oil prices go up, natural-gas prices go up as well. This is particularly true for prices of spot cargos (natural gas purchased for immediate delivery). Spot prices are largely based on current prices at Henry Hub (natural-gas pipeline hub in Louisiana), and these, in turn, are strongly influenced by oil prices. Although some existing LNG contracts have built-in price ceilings, in the long term the prices for new natural-gas contracts and contract renewals will also fluctuate with oil prices.

A spike in oil prices can affect a country's economic performance in several ways. Higher oil prices trigger a direct transfer of income from oil-importing countries to oil-exporting countries. Japan, for example, has no oil resources of its own and consumes about 5 million b/d of oil. If oil prices increase by US$10 per barrel, this amounts to an additional income transfer of US$50 million per day from Japan to the countries that supply its oil. It adds up to more than US$18 billion over the course of a year.

In addition to this direct transfer of income, higher oil prices increase the cost of industrial production, which reduces output and contributes to inflationary pressure. Consumers feel the pinch as higher prices for petroleum products and a variety of other goods. The cumulative effect is a deterioration in living standards, a slowdown in economic growth, and, ultimately, an increase in unemployment. The impact obviously varies among countries, but overall, the Asia-Pacific region is a major net oil importer, and most economies in the region suffer when oil prices are high.

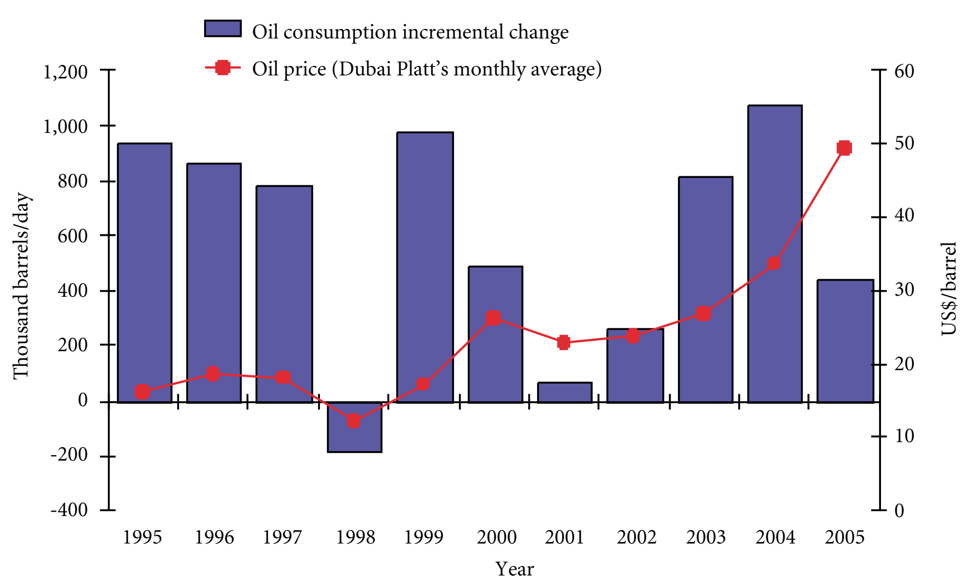
Market observers and researchers have closely watched the impact of oil prices on economic growth since the oil price shocks of the 1970s. A study by

Table 1.1. Hypothetical impact of an oil price increase of US$10 per barrel on selected Asian economies, second quarter 2004 through fourth quarter 2005 (percent)

	Impact of oil price increase (percent)	
Country/economy	Consumer prices	Gross Domestic Product (GDP)
China	+0.5	–0.8
India	+1.7	–0.8
Indonesia	+1.3	+0.1
Japan	+0.7	–0.5
Malaysia	+1.4	–0.9
Philippines	+1.4	–1.9
Republic of Korea	+0.8	–0.6
Singapore	+1.3	–1.7
Taiwan	+0.3	–0.4
Thailand	+1.5	–2.2

Source: Park (2004).

Figure 1.11. Annual incremental change in oil consumption in the Asia-Pacific region and global oil prices, 1995–2005



Source: FACTS Global Energy (2006).

the Asian Development Bank (Park 2004) examines the impact of a US$10-per-barrel increase in the price of oil extending from the second quarter of 2004 through the fourth quarter of 2005. As might be expected, developing economies that are heavily dependent on oil imports (such as Singapore, the Philippines, and Thailand) are most affected (Table 1.1). More-mature economies (such as Japan and South Korea) and those that are oil exporters (such as Indonesia and to some extent Malaysia) experience a smaller impact. In South, Southeast, and East Asia as a whole, a US$10-per-barrel rise in oil prices would raise consumer prices for all goods by an estimated 1 percent and reduce GDP growth by 0.6 percent. In Thailand—the country worst affected in this hypothetical scenario—GDP growth would be reduced by more than 2 percent.

Because even small changes in consumption or production can trigger large swings in energy prices, the Asia-Pacific region has also come to play a critical role in global energy markets, particularly in the market for oil. When oil consumption increases in Asia and the Pacific, global prices generally rise (Figure 1.11). Conversely, when oil consumption levels off in the region, global prices generally stagnate, as seen during the 1997–1998 Asian economic crisis.

Since 2003, the dual impact of global supply uncertainty and an enormous increase in Chinese consumption, as well as consumption in the United States and the Middle East, has contributed to a sharp rise in oil prices everywhere in the world. Thus, the Asia-Pacific region's growing dependence on imported energy has helped cause an energy-security dilemma of global proportions.

CHAPTER TWO

The Environmental Context of Energy

Toufiq A. Siddiqi

Air pollution hangs over an industrial area in Kawasaki, Japan. Policymakers in the Asia-Pacific region must search for a balance between environmental concerns and the economic aspirations of their people. © Michael S. Yamashita/Corbis

Along with growing dependence on imported oil and natural gas, environmental concerns associated with increased energy use are at the heart of the Asia-Pacific energy-security dilemma. How will societies in the region balance concerns about air, water, and land pollution with the economic aspirations of their people? And as the environmental impact of energy use transcends national—and even regional—boundaries, how will countries in the region and around the world devise and enforce international agreements to make sure that economic development in one country does not come at the expense of environmental problems somewhere else?

Even efforts to reduce dependence on imported energy involve environmental tradeoffs. Countries can slow down their consumption of imported oil and natural gas by generating electricity with coal, the only fossil fuel that is abundant in the region. Yet coal combustion causes air pollution at local and regional levels and produces greenhouse gases that contribute to global warming. Several countries in the region could also reduce their dependence on imported energy by switching to nuclear power for electricity generation, but the use of nuclear power raises concerns related to accidents, the safe disposal of radioactive wastes, and the possibility of nuclear-weapons proliferation.

All energy sources have some impact on the environment, and every decision about energy use and economic growth has environmental implications. Among energy sources, coal, oil, and biomass (trees, shrubs, and agricultural and animal wastes) cause the highest levels of air pollution (Table 2.1), while coal and biomass produce the most greenhouse gases for the same amount of energy generated (Siddiqi 2000). With growing energy use in Asia and the Pacific, air pollution is becoming an increasingly important problem, particularly in urban areas, and greenhouse gases from the region are making a significant contribution to global climate change.

More efficient use of energy, whatever its source, can lower consumption and thus contribute to achieving environmental goals. Technological improvements can make energy use less harmful. And switching away from coal or oil to natural gas, hydropower, nuclear power, or wind or solar energy can help reduce problems of air quality, acid rain, and global climate change.

Air quality

The largest sources of air pollution are smoke and exhaust from burning fossil fuels and biomass. Outdoor air pollution is particularly critical in the cities of

Table 2.1. Major environmental impacts of energy sources

Impact	Energy source							
	Fuel-wood	Coal	Petroleum products	Natural gas	Hydro-power	Nuclear	Solar	Wind
Air pollution	H	H	H	L	L	L	L	L
Acid rain	H	H	H	L	L	L	L	L
Greenhouse gas emissions	H	H	M	L	L	L	L	L
Impact on oceans	L	L	M	L	M	L	L	L
Impact on inland waters	L	L	M	L	H	L	L	L
Impact on land	H	M	L	L	H	L	L	L
Disturbance to ecosystems	H	M	M	M	H	H	L	L
Solid wastes	L	H	L	L	L	H	L	L
Noise	L	M	M	L	L	L	L	H
Visual	H	H	H	M	L	L	M	M
Disaster potential	M	M	H	M	H	H	L	L

Source: Estimated by author.
Note: H = high impact; M = medium impact; L = low impact.

the Asia-Pacific region, while indoor air pollution, largely from cooking and heating with biomass fuels, tends to be more important in rural areas.

Air pollution in cities stems primarily from motor-vehicle exhaust and smoke from coal used in power plants and factories and for domestic heating. Small particles released by the combustion of coal and petroleum products can cause a wide range of health problems, including respiratory diseases, lung cancer, and heart disease. Air pollutants from fuel combustion also include sulfur dioxide (SO_2), which contributes to acid rain and can cause health problems, particularly among children and the elderly. Another important air pollutant, nitrogen dioxide (NO_2), is a poisonous gas. When combined with hydrocarbons and sunlight, NO_2 produces photochemical reactions and smog. Unhealthy levels of these pollutants are found in the ambient air of many cities in the region (Table 2.2).

The World Health Organization (WHO) has recommended guidelines for maximum concentrations of SO_2 and nitrogen oxides (NO_x) in the ambient atmosphere, as given in Table 2.2. WHO has not yet recommended a guideline for small particles, so the table includes the U.S. Environmental Protection Agency (EPA) air-quality standard for particulate matter (PM_{10}).

Out of 29 cities that had particulate-matter counts above the EPA standard in 1999, 27 were in the Asia-Pacific region (World Bank 2005). They included, among others, Beijing, Chongqing, Shanghai, and Tianjin in China; Delhi, Kolkata (formerly Calcutta), and Mumbai (formerly Bombay) in India; Jakarta in Indonesia; and Bangkok in Thailand.

Table 2.2. Air pollution in selected cities of Asia and the Pacific

Country	City	Urban population (millions, 2005)	Particulate matter[ab] (1999)	SO_2[ac] (1995–2001[d])	NO_2[ac] (1995–2001[d])
Australia	Sydney	4.39	22	28	81
China	Beijing	10.85	106	90	122
	Chongqing	4.98	147	340	70
	Shanghai	12.67	87	53	73
	Tianjin	9.35	149	82	50
India	Delhi	15.33	187	24	41
	Hyderabad	6.15	51	12	17
	Kolkata	14.30	153	49	34
	Mumbai	18.34	79	33	39
Indonesia	Jakarta	13.19	103	NA	NA
Japan	Tokyo	35.33	43	18	68
	Yokohama	3.37	32	100	13
Malaysia	Kuala Lumpur	1.39	24	24	NA
New Zealand	Auckland	1.15	15	3	20
Philippines	Manila	10.43	60[e]	33	NA
Republic of Korea	Pusan	3.53	43	60	51
	Seoul	9.59	45	44	60
Singapore	Singapore	4.37	41	20	30
Thailand	Bangkok	6.60	82	11	23
WHO recommended guidelines			—	50	40
EPA standards			65–75	—	—

Sources: World Bank (2005); WHO (2000); EPA (2005).
[a] Micrograms per cubic meter.
[b] Average annual concentrations in residential areas of particulates smaller than 10 microns.
[c] Average annual concentrations.
[d] Data are for the most recent year available.
[e] Data are for 2000.
NA = not available.

Among the cities with ambient concentrations of SO_2 exceeding WHO guidelines are Beijing, Chongqing (the highest level among the cities shown), Shanghai, and Tianjin in China, Kolkata (estimated for 2005) in India, Yokohama in Japan, and Pusan in the Republic of Korea (South Korea). Cities with NO_2 levels exceeding WHO guidelines include the same four cities in China, Delhi in India, Tokyo in Japan, and Pusan and Seoul in South Korea.

Air pollution in other cities of the region, such as Karachi and Lahore, may well exceed the WHO/EPA standards. For many cities, however, reliable data on SO_2 and NO_2 concentrations and on particulate-matter levels and are not available.

As if the current situation were not serious enough, air pollution is expected to worsen in many of these cities, as well as in several smaller cities of the region. Much of the increase in air pollution in Asian and Pacific cities stems from the growing number of motor vehicles. Between 1990 and 1999–2001, the number of motor vehicles per capita more than doubled in South Korea, the Philippines, India, and China (Table 2.3). The total number of motor vehicles increased at an even faster pace because populations were also growing during this period. Between 2004 and 2015, the number of motor vehicles is projected to more than double in most Asian countries. Increased traffic congestion, which results in more emissions per distance traveled, will also add to air pollution.

The use of coal for electricity generation and industry contributes significantly to urban air pollution. Since 1980, coal use has grown in nearly every major country of the region, and it is expected to continue growing (see Appendix Table 2.1). In many cases, the rising use of coal will cause higher levels of air pollution, acid rain, and greenhouse-gas emissions.

Although most outdoor air pollution originates in the region's major cities, it extends—in the form of acid rain (more accurately referred to as acid precipitation)—far beyond urban boundaries and national borders. Acid rain results primarily from emissions of SO_2 and NO_x produced from the burning of coal. When released into the atmosphere, these gases react with water, oxygen, and other chemicals to form a solution of sulfuric and nitric acid, which can be carried over long distances by prevailing winds before returning to earth in rain, snow, fog, or dust. Acid rain can damage forests and soils, fish and other animals, building materials, and human health.

Acid rain is a growing concern in the region, particularly in East Asia. The highest levels have been measured in southern China where a great deal of high-sulfur coal is burned (Figure 2.1). Prevailing winds can spread acid rain from this region as far as South Korea and Japan.

Forest fires also cause widespread haze in Southeast Asia. In 2005, fires on the Indonesian island of Sumatra caused Malaysia to declare a state of emergency in the two coastal cities of Kuala Selangor and Port Klang, where the residents were advised to stay indoors. Schools were closed in the central state of Selangor and in Kuala Lumpur, the capital city.

Droughts and the illegal burning of rain forests by farmers and loggers are blamed for the periodic episodes of haze. The prolonged and extensive haze over Malaysia, Singapore, and Indonesia during 1997 caused several billion dollars in economic loss due to a decline in tourism and agricultural production (Arnold 2005), in addition to harmful effects on human health. Although forest fires are not strictly an energy issue, energy-related air pollution adds to pollution from fires, resulting in a much greater health impact.

Table 2.3. Growth in per-capita number of motor vehicles in selected Asia-Pacific countries, 1990 to 1999–2001: Number of vehicles per 1,000 population and percent increase

Country	Number of vehicles per 1,000 population 1990	Number of vehicles per 1,000 population 1999–2001	Percent increase
China	5	12	140
India	4	10	150
Indonesia	16	25	56
Japan	469	572	22
New Zealand	524	696	33
Pakistan	6	9	50
Philippines	10	32	220
Republic of Korea	79	255	223
Singapore	130	168	29

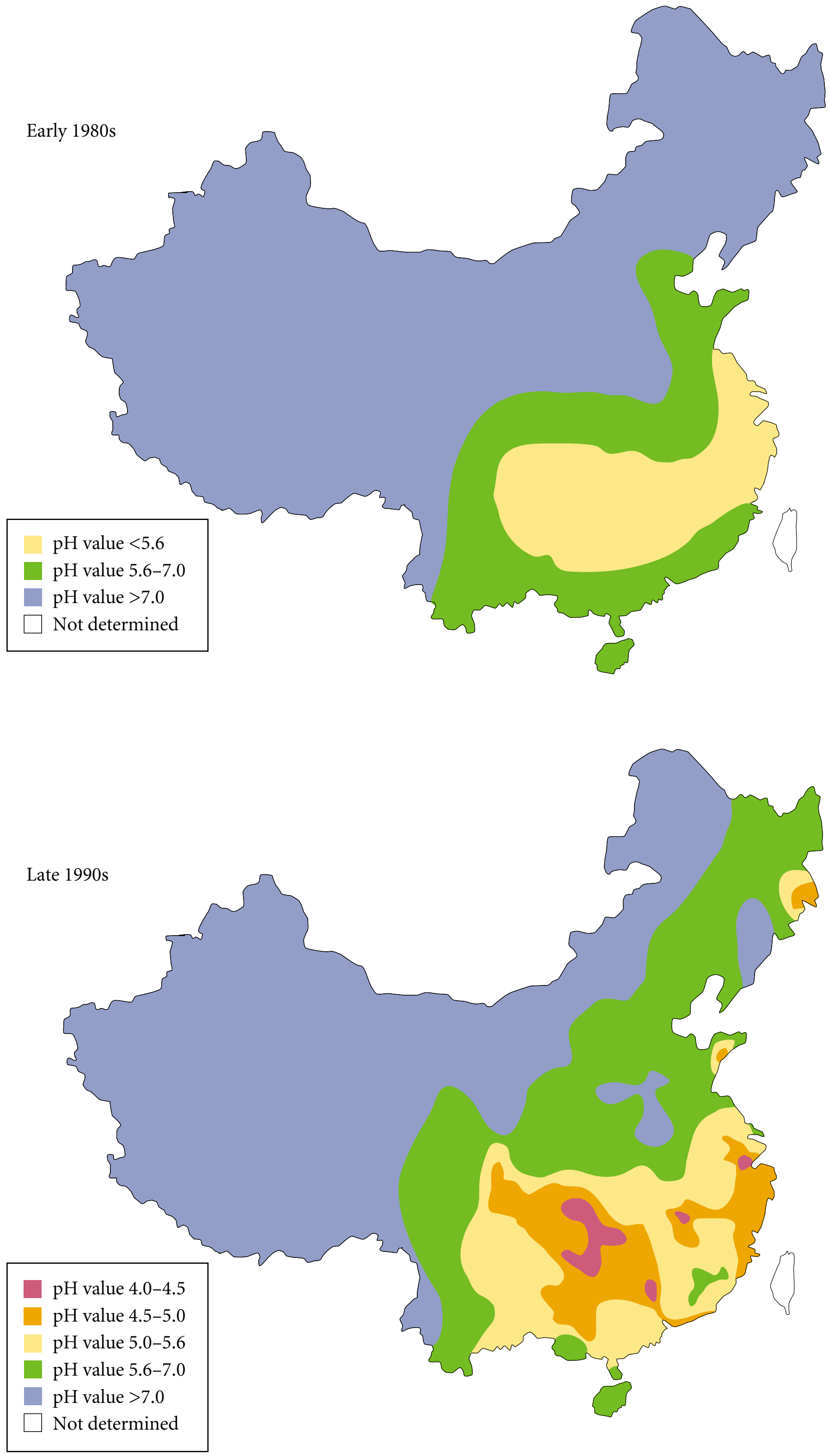
Source: World Bank (2004).

Several of the region's largest cities have managed to reduce at least some air pollutants. The decline in lead concentrations in Bangkok is one example. In Seoul, concentrations of SO_2 have fallen dramatically—from 0.094 parts per million (ppm) in 1980 to less than 0.001 ppm in 2000. Concentrations of nitrous oxide (N_2O), particulates, and ozone (O_3) have increased, however (Jeon 2001). Most of this increase is due to the city's rapidly growing number of vehicles—from about 130,000 in 1970 to more than 2 million in 2000. To counter this trend, the Korean government is promoting the use of compressed natural gas (CNG) in buses. While only 77 such buses were in operation in 2000, the number has been increasing rapidly and is expected to reach 20,000 by 2007.

Overall, air quality is improving in a few major cities of the region, holding steady in some, and deteriorating in others, depending on the growing numbers of motor vehicles, the energy sources used for industry and power generation, and government measures to curb emissions (Huizenga, Haq, and Schwela 2003). Air-pollution levels are low and decreasing in Tokyo and Osaka; they are moderate to high but decreasing in Pusan, Hong Kong, Delhi, and Seoul; and they are high but stabilizing in Bangkok, Beijing, Chongqing, Kolkata, Metro Manila, Mumbai, and Shanghai. In most other cities of the region, air pollution is getting worse.

While combustion of fossil fuels is the major source of air pollution in urban areas, burning fuelwood and agricultural and animal wastes is the largest source of air pollution in the countryside. Exposure to pollutants from biomass combustion is particularly harmful to women who use biomass fuels to cook under conditions of poor ventilation. It is also harmful to young children who are often nearby while their mothers are cooking.

Figure 2.1. Increase in acidity (lower pH values) of precipitation in China, early 1980s to late 1990s



Source: Based on He, Huo, and Zhang (2002). Reprinted with permission from the publisher.

WHO estimates that indoor air pollution causes 1.6 million deaths per year in developing countries. About 550,000 of these deaths occur in India alone (Walsh 2004). Rural women and their children are often exposed to many times higher levels of harmful pollutants than are urban dwellers. A recent survey on indoor air pollution in Bangladesh (Dasgupta et al. 2004) found that women and children were exposed to twice the level of pollutants as men. The authors estimated that the exposure of children could be reduced by half with two simple measures: increasing their time outdoors from three to five or six hours a day and concentrating their outdoor time during peak cooking periods.

Global climate change

There is general scientific consensus, documented in the reports of the Intergovernmental Panel on Climate Change (IPCC), that emission of greenhouse gases is the most important human activity contributing to global climate change (WMO and UNEP 2001). The gases that contribute most to climate change are carbon dioxide (CO_2), methane (CH_4), N_2O, halocarbons, and tropospheric ozone. Slightly more than one-half of the total effect is due to CO_2, and about two-thirds of the CO_2 is produced from energy conversion, primarily from the combustion of coal, oil, natural gas, and biomass. Natural gas is mainly composed of methane, and methane leaks from producing areas and from pipelines also contribute to global climate change.

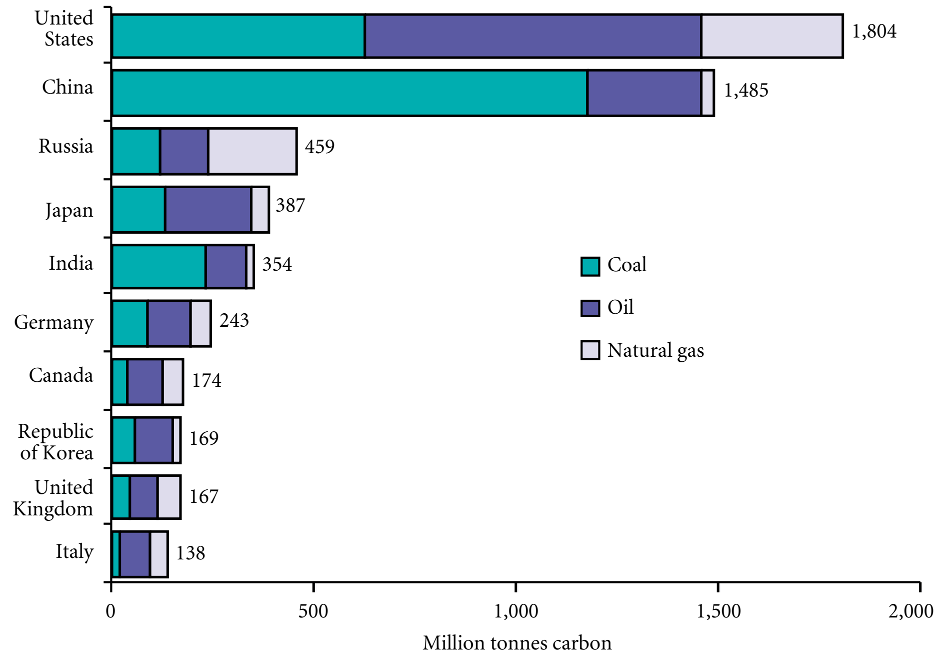
Greenhouse-gas emissions from developing countries in Asia are increasing due to growing populations and rapid industrialization. Among the 10 countries in the world with the highest CO_2 emissions from fossil-fuel use, China ranks second (after the United States) and India fifth (Figure 2.2). Two of Asia's developed countries also rank in the top 10—Japan (fourth) and South Korea (eighth). In China and India, coal makes the largest contribution to total CO_2 emissions; in Japan and South Korea, the largest contributor is oil.

Although high in absolute terms, greenhouse-gas emissions from the large developing countries of Asia are much lower on a per-capita basis than emissions from the world's industrialized nations. In terms of CO_2 emissions, one person in the United States has a greater negative effect on the environment than more than six people in China or nearly 21 people in India (Figure 2.3).

This contrast in per-capita CO_2 emissions has been a major issue obstructing international agreements on global climate change. Although still comparatively low, per-capita emissions in many developing countries are increasing rapidly. China, for example, is expected to become the world's largest emitter of CO_2 by 2009. Policymakers in Washington and representatives of energy-intensive industries have argued that limiting emissions in the United States will have serious economic consequences if no limits are placed on the larger developing countries such as China and India (see, for example, Victor 2004).

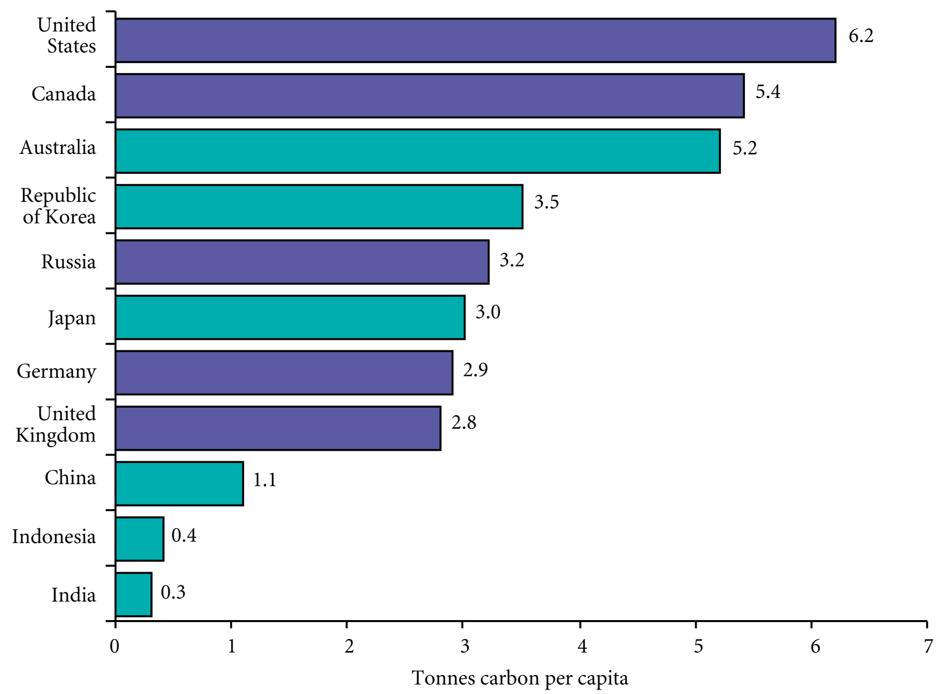
Meanwhile, representatives from almost all developing countries, including

Figure 2.2. Annual total CO_2 emissions (million tonnes of carbon) from major emitting countries due to combustion of coal, oil, and natural gas, 2005



Source: Calculated by the author from BP (2005).

Figure 2.3. Annual per-capita CO_2 emissions (tonnes of carbon) from all fossil-fuel combustion in selected large countries of the world, 2005



Source: Calculated by the author from BP (2005).
Note: Countries/economies in the Asia-Pacific region are shown in green.

The United Nations Framework Convention on Climate Change (UNFCCC) was signed at the World Summit in Rio de Janeiro in 1992. The Kyoto Protocol, which spells out the actions to be taken under the Convention, was opened for signatures in 1998. After ratification by the Russian Federation in November 2004, the Protocol came into force in February 2005. The effectiveness of the Protocol is substantially hampered, however, because the United States (along with Australia and a few smaller countries) has not ratified it.

A major reason given by the United States for not ratifying the Kyoto Protocol is that it requires that industrialized nations as a whole reduce greenhouse-gas emissions to about 5 percent below 1990 levels over a five-year period from 2008 to 2012. Developing countries are not required to reduce their emission levels. Because the United States has continued to increase emissions since the Kyoto Protocol was formulated, it would now need to reduce current levels by about 30 percent to meet the Kyoto targets.

Most reductions would have to come from a decrease in CO_2 emissions associated with the use of fossil fuels, primarily coal and petroleum products. In the United States, where 51 percent of electricity is generated from coal (EIA 2004), there has been strong opposition to building nuclear power plants, and most of the economically feasible hydropower capacity is already being utilized. Thus reductions in energy-related emissions would have to come from improvements in energy efficiency and greater use of natural gas, wind, and solar energy. U.S. policymakers feel that complying with these requirements would hurt the competitive position of the United States with respect to large developing countries such as China and India, which are not required to reduce their emissions.

The Kyoto Protocol also includes provisions such as emissions trading and the Clean Development Mechanism (CDM). Emissions trading allows one country to meet some of its obligations under the treaty by obtaining "emission-reduction credits" from another country. For example, an industrialized country might obtain emission-reduction credits by providing economic assistance to a developing country in return for a pledge that the developing country would retain a certain area under forests. The CDM provides guidelines for joint projects in which an industrialized country receives emission-reduction credits when it funds a project in a developing country where emissions are reduced. There have been some limited applications of these provisions on a bilateral basis and through multilateral organizations such as the World Bank.

The Kyoto Protocol, by itself, will not stabilize greenhouse-gas emissions. The national emission targets set by the Protocol for 2008–2012 need to be followed by successive rounds of targets, to be negotiated on a rolling basis. It may also be necessary, as a recent study for the Pew Center on Global Climate Change (Aldy et al. 2003) suggested, to place more emphasis on complementary or alternative approaches that go beyond quantified emission reductions. Such policies might focus on technology standards and accelerated research and development.

The Asia-Pacific Partnership on Clean Development and Climate represents a complementary approach. The United States launched the Partnership with Australia, China, India, Japan, and South Korea in 2005 (U.S. Department of State 2005). Among other initiatives, the Partnership will:

- Collaborate to promote the development and diffusion of existing and emerging technologies and practices that are cost effective and reduce stress on the environment. Areas of cooperation include energy efficiency, clean technologies for the use of coal, increased use of liquefied natural gas (LNG), carbon capture and storage, methane capture and use, non-military nuclear power, rural/village energy systems, and renewable energy technologies
- Cooperate on the development and diffusion of longer-term transformational technologies that will promote economic growth while enabling significant reductions in greenhouse-gas intensities. Areas for mid- to long-term collaboration include hydrogen, next-generation nuclear fission, and nuclear fusion
- Help build human and institutional capacity to strengthen cooperative efforts, seeking opportunities to engage the private sector

The vision statement of the Partnership mentions that its goals are consistent with those of the UNFCCC. No mention is made of the Kyoto Protocol, however, since the Partnership is meant to provide a supplementary approach. In this context, Japan's role in the Partnership is especially noteworthy, since Japan has a strong commitment to reduce its emissions as specified under Kyoto.

ASSIGNING A COST TO AIR POLLUTION

The World Bank (1992) has estimated that 2 to 5 percent of all deaths in urban areas in the developing world are due to exposure to high levels of airborne particulates. SO_2, NO_x, volatile organic compounds, lead, and carbon monoxide (CO) also have significant adverse effects on human health.

There have been a number of attempts to estimate the economic cost of pollution-related health problems. The Asian Development Bank (1999) estimated annual economic losses due to death and illness caused by airborne particulates and lead at US$2.1 billion in Jakarta and US$2.5–6.3 billion in Bangkok.

The elimination of lead from gasoline in Bangkok, fully implemented in 1995, is one of the best-known success stories of improving air quality in the Asia-Pacific region. The average level of lead in blood samples taken from traffic policemen declined from 22.3 milligrams per deciliter (mg/dl) in 1995 to 5.5 mg/dl in 2000 (Wangwongwatana 2002). The proportion of school children with lead concentrations of more than 10 mg/dl dropped from 26 percent in 1993 to 2 percent in 2000. The economic benefit of reducing lead pollution in 2000 alone was estimated at US$175 million.

China and India, point to the gap in current per-capita emissions levels. They maintain that most accumulated greenhouse gases in the atmosphere today have come from the industrialized nations and these nations should reduce their emissions before asking the developing nations to do so. If the goal is to reduce the effects of human activities on climate change, the concerns of both developing and industrialized nations will need to be addressed.

In the period up to 2015, CO_2 emissions are expected to continue increasing in most of the countries of the Asia-Pacific region (Table 2.4). Factors that will affect the rate of increase include the overall economic growth rate, the energy intensiveness of national economies, and the choice of energy sources. Countries that rely heavily on coal, such as China, India, and Australia, will find it more difficult to slow down increases in CO_2 emissions than countries that put more emphasis on natural gas or hydropower, such as Bangladesh, Pakistan, Malaysia, and New Zealand.

Table 2.4. Projected growth in CO_2 emissions from fossil fuels in selected Asia-Pacific economies, 2005 actual and 2015 projected: Million tonnes of carbon and percent change

	Million tonnes of carbon		
Country/economy	2005	2015	Percent change[a]
Australia	106	126	19
Bangladesh	11	19	76
China	1,485	2,310	56
China, Hong Kong SAR[b]	21	25	19
India	354	481	36
Indonesia	96	122	27
Japan	387	389[c]	1
Malaysia	41	52	27
New Zealand	11	11[c]	5
Pakistan	36	54	50
Philippines	21	29	38
Republic of Korea	168	229	36
Singapore	40	53	33
Taiwan	85	115	35
Thailand	67	92	37
Vietnam	19	41	116

Sources: Calculated by the author from BP (2006) and FACTS Global Energy (2006) for 2005 and from FACTS Global Energy (2006) for 2015.
[a] Calculated from more exact values than shown in preceding two columns.
[b] Special Administrative Region.
[c] Projections for 2015 will need to be reduced to meet Kyoto-Protocol requirements.

Hydropower and nuclear energy: Advantages and disadvantages

Hydropower. Water has been used on a small scale as a source of energy for centuries. The rapid growth in the use of electricity in the early 20th century increased the demand for hydropower, and thousands of small and large dams were constructed for power generation. Hydropower as a source of electricity has a high initial capital cost, but a low operating cost. On a small scale, it is generally considered to be a clean and environmentally friendly energy source.

The potential for using hydropower to generate electricity depends on the configuration of flowing water and the distance from centers of demand (World Commission on Dams 2000). Not surprisingly, the most promising sites were developed first. Today, more difficult and controversial sites are being examined for development.

During 2005, the Asia-Pacific region produced roughly 25 percent of the world's total hydropower for electricity generation, equivalent to about 3.4 million barrels of oil per day (boe/d) (BP 2006). China produced more than one-half of Asia's total electricity from hydropower, at 1.8 million boe/d. Japan, India, Pakistan, New Zealand, and Australia also generated significant amounts of hydro-electricity.

There is usually no opposition to the development of small-scale hydropower plants that can supply electricity to hundreds or a few thousand households. By contrast, the construction of large dams for hydropower frequently inundates vast areas of agricultural land, disrupts natural ecosystems, and displaces entire communities. During recent years, there has been strong opposition to such projects, including the Sardar Sarovar Dam on the Narmada River in India and the Three Gorges Dam on the Yangtze River in China.

Choosing between energy sources always involves tradeoffs, and hydropower is no exception. The Three Gorges Dam, for example, will be the largest hydropower project in the world, generating about 16,000 megawatts (MW) of electricity. If this same amount of electricity were to be generated using coal, it would result in the emission of about 140 million metric tons (tonnes) of CO_2 a year. In addition, the emission of particulates, SO_2, and other gases would have substantial negative effects on human health.

China already suffers from electricity shortages, and demand is certain to increase. There is no question that the Three Gorges project will contribute to economic growth, and the dam will help to control floods on the Yangtze River. Nevertheless, the project has entailed the relocation of almost one million people and the loss of valuable ecosystems and agricultural lands. In 2003, the government of China's Sichuan Province decided to drop plans to build a dam on the Min River, one of the main tributaries of the Yangtze, due to public and media opposition (Economy 2004).

Nuclear energy. Like hydropower, nuclear energy is used primarily to generate electricity. In 2005, Asia and the Pacific accounted for about 20 percent of the world's total electricity generated from nuclear power. More than one-half of this was in Japan and another one-fourth in South Korea (BP 2006). The rest was in China, India, Pakistan, and Taiwan.

The nuclear-power sector is growing particularly quickly in China and India. Output in China increased by about 74 percent in 2003 and by another 14 percent in 2004, making China the third largest producer of nuclear energy in the region. As of mid-2005, China's nuclear power capacity stood at 7,916 MW. This capacity is expected to triple by 2020, over a period of 15 years. The nuclear-power capacity of India is projected to increase from 2,770 MW in 2005 to 6,730 MW in 2008, with a target of 20,000 MW by 2020 (JAIF 2005). Pakistan has two relatively small nuclear power plants in operation, and a third is under construction with assistance from China.

High initial costs, combined with problems related to storing radioactive wastes, concerns about accidents, and pressure to adhere to nuclear non-proliferation treaties, deter most countries in the region from using nuclear energy. New Zealand, for example, passed legislation in 1987 that excluded the use of nuclear power for any purpose. Australia's large reserves of high-quality coal have made it unnecessary to rely on nuclear power to generate electricity. To be economically viable, nuclear power plants must be large, making them unsuitable for countries with small populations and low total electricity demand.

Well-publicized nuclear accidents such as at Three Mile Island in the United States and Chernobyl in the former Soviet Union have led to a re-examination of the role of nuclear power in the energy supply of developing countries. Radiation from the Chernobyl accident spread to many countries in Europe and beyond. Thousands of people were evacuated, animals that grazed in the area could not be used for food, and millions of acres of agricultural land could not be used for years.

In August 2004, Japan suffered its worst nuclear accident, with four workers killed and another seven injured. This took place at a power plant west of Tokyo. Fortunately, there was no radiation leak, but such an accident is still cause for concern. Japan obtains about 30 percent of its electricity from nuclear energy, and even a temporary closure of nuclear plants could cause substantial disruption throughout most of the country.

In October 2000, anti-nuclear groups in Taiwan were able to halt construction of a nuclear power plant on the northeastern coast. According to the Taiwan Environmental Action Network, multinational corporations such as General Electric, Hitachi, Mitsubishi, and Toshiba have large stakes in the construction of the US$5.6 billion project and are exerting pressure on the government to keep the project alive.

Nuclear energy presents a classic example of the tradeoffs involved in decision-making on energy and the environment. In routine operation, nuclear power has much less environmental impact than fossil fuels. The probability of an accident is low, but should one occur, the implications could be significant for millions of people both within and beyond national borders. Another critical issue is the secure disposal of radioactive wastes for hundreds or thousands of years, including making sure that they do not fall into the hands of terrorists. Nuclear energy could play a major role in reducing global climate change, but in helping to solve one problem it could create others.

Alternative energy sources

When the price of oil and other fossil fuels shot up during the 1970s, there was renewed interest in alternative energy sources such as photovoltaic (PV) solar cells, wind turbines, and geothermal energy. When fuel prices went down in the 1980s, research and development funds for alternative energy sources also declined.

More recently, the revival of interest in renewable and other alternative energy sources stems from concern about air pollution and global climate change. The UNFCCC and the Kyoto Protocol have been major catalysts for the development of more reliable and efficient wind turbines, PV systems, and solar thermal panels. The rise in oil and natural-gas prices since 2004 has given added impetus to the development of alternate energy sources.

Until just a few years ago, the common perception was that renewable energy might play a significant role in energy supply one day. That day seems to be approaching much faster than many people thought.

The annual worldwide investment in renewable energy reached US$38 billion during 2005, an increase of US$8 billion from a year earlier (REN21 2006). Germany and China were the largest investors, contributing about US$7 billion each. The United States invested about one-half of this amount, or US$3.5 billion, followed by Spain and Japan with more than US$2 billion each, and then India. These numbers include investments in small, but not large, hydropower facilities. Investments in large hydropower plants totaled roughly US$15–20 billion in 2005.

Another indication of the rapid growth of renewable energy is the expansion of installed capacity, particularly for generating electricity. Total global installed capacity for wind power in 2005 was 59,000 MW (REN21 2006), the equivalent of about 60 average-sized nuclear-power plants. Among Asian countries, India's wind-power capacity of 4,200 MW is the fourth largest in the world, after Germany, Spain, and the United States (CECL 2006). At the end of 2005, China had a total installed wind-power capacity of 1,260 MW (Li et al. 2006), mainly in small projects. Japan had a slightly smaller capacity, at 1,230 MW.

Stand-alone electricity systems are particularly important for the millions of people in Asia and the Pacific who still lack electricity for lighting and other basic uses, particularly in remote rural areas that are not connected to national grids. In China, where about 30 million people have no access to electricity (Ku, Lew, and Ma 2003), the government completed a Township Electrification Program in 2005 that provides electricity from PV systems, small hydropower facilities, and small wind turbines to about 200,000 households in 1,000 townships (REN21 2006). The next phase of the program is projected to provide electricity from renewable sources to 3.5 million rural households in 10,000 villages by 2010. Full rural electrification is planned by 2015. The ongoing rural electrification program in Thailand has already provided solar home systems to almost 200,000 households. In Sri Lanka, about 20,000 homes were provided with PV solar systems, and 900 received small hydropower systems during 2005 alone.

Over the past few years, many countries, including several in Asia and the Pacific, have established policy targets for the share of total energy or total electricity to be supplied by renewable sources. China has announced a revised target of 16 percent of total primary energy to be provided by renewable sources (including large hydropower projects) by 2020, up from 7.5 percent in 2005. China's 2020 targets for specific sources include 300,000 MW from hydropower, 30,000 MW from wind power, 30,000 MW from biomass, 1,800 MW from PV systems, and smaller quantities from geothermal and solar thermal power (REN21 2006). If these goals are achieved, China will be the clear leader in almost all forms of renewable energy.

As a short-term target, India plans to use renewable sources for 10 percent of additional electrical capacity. This includes cogeneration of power in sugar production and other industries that use energy from biomass. Although not yet established formally as targets, several long-term goals have also been proposed by the Indian government. These include using renewable sources to supply 15 percent of all electricity and switching 10 percent of current oil consumption to biofuels, synthetic fuels, and hydrogen by 2032 (REN21 2006). Pakistan has announced targets of supplying 5 percent of all electricity from renewable sources by 2030 and installing 1,100 MW of wind power much sooner.

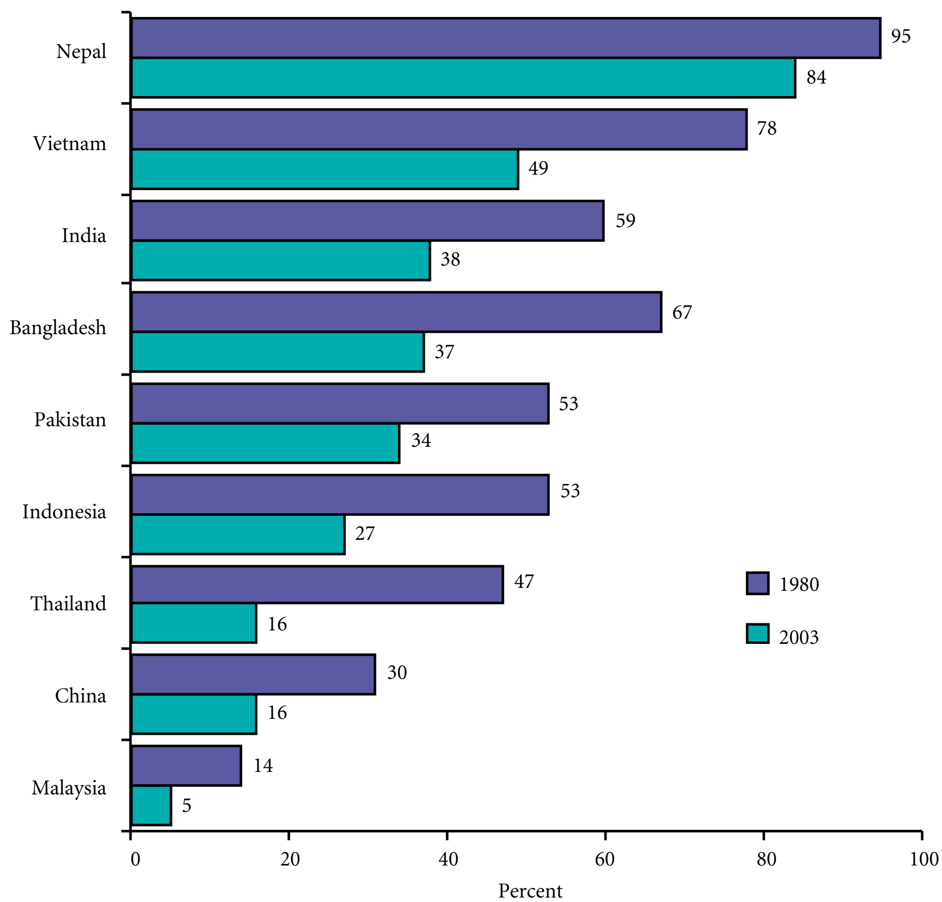
Several countries have introduced a mixture of incentives, including tax breaks and guaranteed prices, to help increase the use of renewable energy. For example, the boom in the construction of Indian wind-power facilities during the 1990s was driven by tax incentives that enabled developers to recover the full investment costs of wind farms in the first year of operation (Martinot et al. 2002). Six Indian states have guaranteed prices for renewable energy that supplies existing power grids. The Australian government provides a subsidy of US$3.15 per watt of installed PV capacity.

Although not strictly renewable, geothermal power shares many features with wind and solar power. This is because geothermal resources are generally expected to last for centuries, and the environmental impact of exploiting them is usually small. Geothermal projects often discharge superheated water and dissolved solids into streams or lakes, however, with adverse effects on aquatic ecosystems. Four of the world's largest users of geothermal energy are in the Asia-Pacific region—the Philippines (second highest capacity in the world), Indonesia (fourth highest), Japan, and New Zealand. Over the next 10 years, the use of geothermal energy for electricity generation is expected to increase globally by more than 6 percent a year, and much of this growth will be in the Asia-Pacific region.

Traditional biomass sources of renewable energy, such as fuelwood and agricultural and animal wastes, still supply about 7–11 percent of primary energy in the world as a whole (Martinot et al. 2002). The contribution of energy from these sources is much higher in many developing countries of Asia and the Pacific. In 2003, more than one-third of the total primary energy used in Bangladesh, India, Myanmar, Nepal, Pakistan, Sri Lanka, and Vietnam came from traditional biomass.

In the region as a whole, consumption of traditional biomass energy sources increased by 41 percent between 1980 and 2003 (Appendix Table 2.2), despite the fact that fuelwood is generally becoming more scarce. The share of energy consumption from biomass sources went down in most countries (Figure 2.4),

Figure 2.4. Share of total energy supplied by combustible biomass and wastes, selected Asia-Pacific countries, 1980 and 2003



Sources: OECD/IEA (2005a; 2005b).

however, because the use of fossil fuels increased even more quickly. In New Zealand, the share of biomass energy sources increased slightly between 1990 and 2003 because tree plantations were developed for energy production.

The environmental impact of burning traditional biomass fuels is similar to the harmful impact of burning coal, both in terms of local air pollution and global climate change. "Cleaner" technologies can reduce local air pollutants, but not CO_2, the main contributor to climate change. To decrease CO_2 emissions, development plans in rural areas will need to include provision of alternative energy sources where feasible, so that communities can become less dependent on biomass.

More efficient energy use

One important way to reduce the adverse environmental impact of energy use is to improve energy efficiency—that is, to consume less energy while maintaining the same output of goods and services. Industrialized countries all over the world improved energy efficiency when oil prices shot up during the 1970s. Concerns that reductions in energy use might slow down economic growth have generally not been borne out. In fact, the countries that were first to develop energy-efficient technologies were able to increase exports to other countries and thus actually benefited economically.

Japan, in particular, was able to achieve significant efficiency improvements in several sectors. During the 1980s, Japanese manufacturers introduced automobiles that gave better mileage per gallon than earlier models. With these energy-efficient models, they captured a sizable share of the automobile market in the United States and in many Asia-Pacific countries. The same scenario appears to be playing out again following the oil price hikes of 2004 and 2005.

Improvements in energy efficiency and structural changes in the economy—shifting from heavy industry toward more emphasis on the information sector—have helped China achieve high rates of economic growth with relatively small increases in energy consumption (Zhang 2003). India's increasing focus on the information industry is also leading to a decline in energy use per unit of gross domestic product (GDP). Similar trends are beginning to emerge in several other developing countries of the region.

Policy considerations

Over the past 30 years, policymakers concerned with the energy sector have begun to place more emphasis on environmental issues. This shift began in the industrialized countries, where environmental problems associated with energy use had been evident for some time. During recent years, serious health effects from air pollution have also led developing countries to consider environmental factors in formulating their energy policies.

In the Asia-Pacific region, Japan was the first country to modify its energy policy to reduce dependence on coal and make greater use of LNG and nuclear power, even though these energy sources were more expensive. South Korea has taken similar steps since the 1980s.

China and India both depend on domestically produced coal for more than one-half of their energy supply, and neither country is in a good position to cut back on the use of coal. Rather, these countries have emphasized improvements in energy efficiency to slow down the expansion of coal use, and they have moved some of the most polluting industries to less-populous areas where fewer people are affected. New installations frequently use improved technologies that make coal combustion less polluting, but it is difficult to shut down and retrofit existing plants given high costs and tight production schedules.

At the local level, perhaps the most important energy-related environmental issue is air pollution in the region's major cities. Unless strong environmental measures are formulated and implemented, expanding populations, industrial development, and growing numbers of motor vehicles are likely to exacerbate air pollution with accompanying effects on human health. Almost all Asia-Pacific countries have air-quality goals and emission standards, but strict, consistent implementation is rare.

Apart from steps taken by individual countries, the need for concerted action at the regional and global level is becoming increasingly apparent. Large-scale issues include haze and acid rain in much of Asia, as well as the region's contribution to global climate change. Progress in addressing these regional and global issues has been slow, partly due to resource scarcity and partly due to politics.

In assessing the outlook up to 2015, there will likely be considerable pressure on the larger countries of the region, including China and India, to address issues of global climate change. The pressure on these countries will increase if the major holdout industrialized countries—the United States and Australia—ratify the Kyoto Protocol or other follow-up agreements designed to reduce future emissions of greenhouse gases.

CHAPTER THREE

Oil

Widhyawan Prawiraatmadja

Kang Wu

Hassaan Vahidy

Fereidun Fesharaki

The large and growing demand for oil in Asia and the Pacific, combined with a limited domestic supply, poses a major challenge for energy security and economic growth. In 2005, the region consumed three times more oil than it produced—23.1 million barrels of oil per day (b/d) consumed compared with only 7.5 million b/d produced. As a result, the Asia-Pacific region is more dependent on imported oil than any other region in the world (Figure 3.1).

With less than 4 percent of the world's proven oil reserves, options to increase or even maintain current levels of oil production in the Asia-Pacific region are few. And efforts to diversify to other types of energy, such as natural gas, have achieved only limited success. Not only is the region heavily dependent on imports to meet its large and growing demand for oil, but it is particularly dependent on oil imports from the Middle East. This dependence on what is perhaps the most volatile and unpredictable part of the world lies at the heart of concerns about energy security in the region.

Limited production potential

Although not sufficient to meet the region's needs, oil production in Asia and the Pacific is not insignificant. China and Indonesia are among the top 20 oil-producing nations in the world, and Indonesia is a member of the Organization of the Petroleum Exporting Countries (OPEC). Malaysia, India, Australia, Vietnam, Brunei Darussalam, and Thailand also produce significant amounts of oil (Appendix Table 3.1).

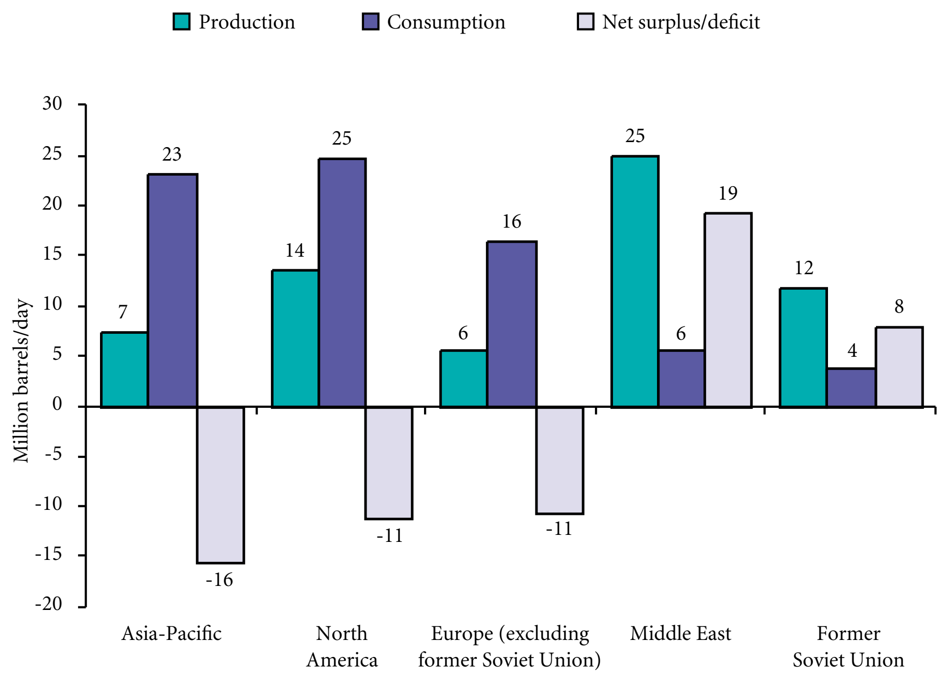
The potential for increasing production, or even maintaining existing levels, is limited, however. In the 10 years from 1995 to 2005, oil production in the region went up by a little over 0.5 percent a year, apparently having reached a plateau in 1997.

According to BP (2006), at the beginning of 2006, the Asia-Pacific region had only 40 billion barrels of proven oil reserves, compared with 59 billion in North America, 141 billion in Europe and Eurasia, and 743 billion in the Middle East. Within the region, China has by far the largest reserves of oil, with 40 percent of the regional total, followed by India, Indonesia, Malaysia, Australia, and Vietnam (Appendix Table 1.8 and Figure 3.2).

If production remains at the 2005 level, the region's proven reserves will last another 14 years—until 2019. Although China has the largest reserves in the region, it is by far the largest oil producer. In fact, China's domestic oil reserves are projected to last only another 12 years at current rates of production.

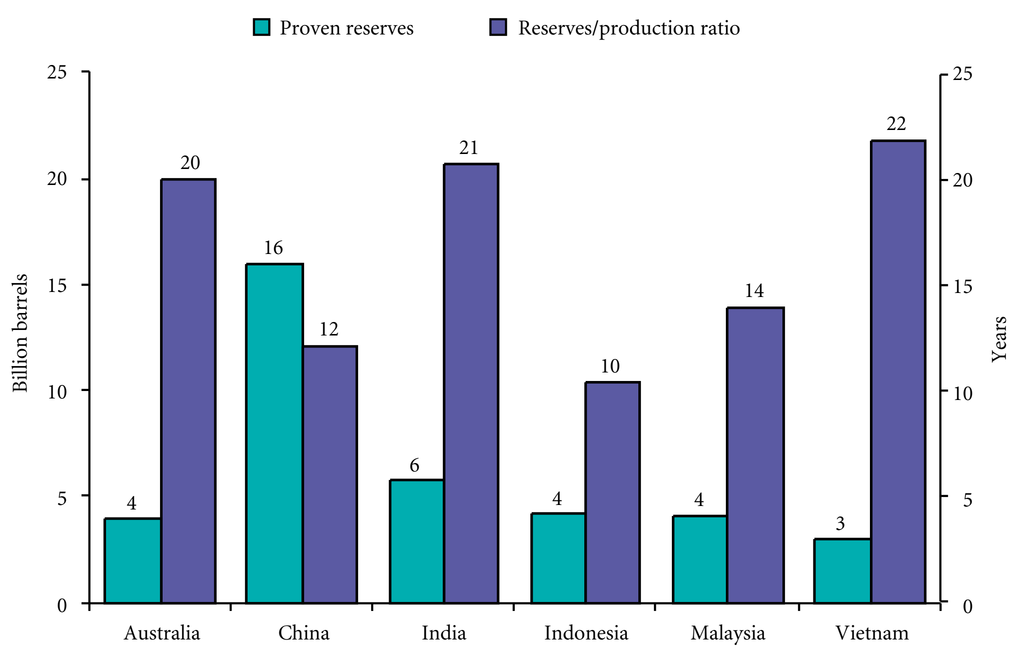
Ships in Singapore harbor. With significant storage and refining capacity, Singapore is the trading hub for petroleum products throughout the Asia-Pacific region. © Macduff Everton/Corbis

Figure 3.1. Oil production, consumption, and net surplus/deficit in major regions of the world, 2005 (million barrels per day: b/d)



Sources: BP (2006); FACTS Global Energy (2006).

Figure 3.2. Proven oil reserves in major countries in Asia (billion barrels) and estimated years of future production, as of 2006



Source: BP (2006).

Among the region's other major oil producers, reserve-to-production (R/P) ratios—used to estimate how long supplies will last—range from 22 years for Vietnam, 21 years for India, and 20 years for Australia to only 10 years for Indonesia (Figure 3.2).

It is important to note that predictions of future energy supplies based on R/P ratios are only indicative. There is no globally accepted system to certify reserves, so reports from individual companies or countries cannot be verified, and measurements of proven reserves are imprecise. In the Asia-Pacific region, new sources of oil may be identified that could help offset the natural decline from existing fields. Yet it is unlikely that total production will increase significantly in the foreseeable future. With consumption already high and growing, Asia and the Pacific will always be dependent on other regions for oil.

Rapidly growing consumption

In 1970, the Asia-Pacific region accounted for 15 percent of global oil consumption. Between 1970 and 2005, oil consumption in Asia and the Pacific grew by an average of 3.5 percent a year, linked to the region's rapid economic growth (Appendix Table 3.2). The general pace of consumption growth slowed to a halt in the early to mid-1980s following an oil price spike and world economic recession, caused in part by the 1979 change of government in Iran. But by 1995, consumption growth had resumed in the region, outpacing consumption growth in the world as a whole. As a result, in 1995 the Asia-Pacific region accounted for 26 percent of global oil consumption, second only to North America at 30 percent. Again in 1997/1998, an economic crisis in the region led to an absolute decline in oil consumption. But this second decline was short-lived. By 2005, Asia and the Pacific accounted for 30 percent of the world's total oil consumption.

Oil consumption in Asia and the Pacific is strongly influenced by the region's largest oil-consuming nations—China, Japan, India, and the Republic of Korea (South Korea). In 1995, China's share of global oil consumption was 5 percent. At that time, Japan was the largest consumer in Asia, second only to the United States at the global level. Despite the Asian economic crisis, which affected most of the region's developing countries, China's strong growth in oil consumption has continued unabated over the past decade. As a result, by 2005, China accounted for about 8 percent of global oil consumption, making it the largest consumer in the region and the second largest in the world—although a distant second behind the United States.

China, Japan, India, South Korea, and Indonesia each consumed more than 1 million b/d of oil in 2005 (Appendix Table 3.1). The combined consumption of these five countries accounted for 75 percent of the region's total oil consumption.

What does the future hold? For the region as a whole, oil consumption is projected to increase at an average annual rate of 2.8 percent (Appendix Table

3.2) between 2005 and 2015. This is slower than the 3.5 percent annual growth in consumption between 1970 and 2005, but it is higher than the projected annual increase for the world as a whole, which is 1.8 percent (Appendix Table 1.1). At these projected rates, by 2015 the Asia-Pacific region will account for nearly one-third of global oil consumption.

As a mature economy, Japan is not expected to increase oil consumption significantly. Indeed, consumption is likely to decline with the projected decline in Japan's population. Following a similar pattern, South Korea's economy will mature, and growth in energy consumption—and oil consumption, in particular—is expected to slow down.

On a per-capita basis, consumption in these and other developed economies of the region is already relatively high, ranging from 14 to 16 barrels of oil equivalent per person per year (Appendix Table 1.3). In this respect, Singapore is a special case, with per-capita consumption at 72 barrels of oil equivalent per year. This extremely high level of oil consumption is misleading, however. It stems from the provision of fuel oil to foreign and Singaporean ships and the use of naphtha by international petrochemical companies operating in the country.

By contrast, per-capita consumption in the region's developing economies is still very low. In 2005, consumption in Bangladesh, China, the Democratic People's Republic of Korea (North Korea), India, Indonesia, Myanmar, Nepal, Pakistan, the Philippines, Sri Lanka, and Vietnam was less than 2 barrels of oil equivalent per person per year. This wide gap in current per-capita oil consumption points to considerable potential for consumption growth in the developing economies of the region. In particular, China's and India's future economic growth will require enormous energy resources, most notably oil.

Oil refining and the market for petroleum products

Several countries in the Asia-Pacific region have a sizeable capacity to refine oil. As a result, the region as a whole imports much more crude oil than it does petroleum products. Currently, crude oil accounts for more than 85 percent of the region's net oil imports. Imports of petroleum products from outside the region are not insignificant, however, and there is considerable trade in petroleum products among countries within the region.

In 2005, the Asia-Pacific region as a whole imported about 5.8 million b/d of petroleum products and exported about 4.0 million b/d. Petroleum products are imported primarily from the Middle East and are exported primarily within the region. Some imports come from Russia and northwestern Europe, however, and some exports go to the Middle East, Africa, and North and South America.

In Asia and the Pacific, most crude oil is consumed as diesel (gasoil) followed in order of importance by gasoline, fuel oil, naphtha, kerosene/jet fuel, and liquefied petroleum gas (LPG) (Figure 3.3). Minor petroleum products include lubricants, asphalt, solvents, and wax.

Are we running out of oil? This question is hotly debated among geologists, economists, and policymakers. Is a growing oil shortage the reason why prices are going up?

The answer is not so simple. The world has many unexplored basins that may contain oil, but the big, low-cost, easily accessible supplies of oil have already been found. The sources of oil that remain to be discovered tend to be smaller, more expensive to recover, and more difficult to deliver to consumers.

Many geologists and petroleum engineers believe that we will approach a "global peak" in oil production before 2015. Many economists do not accept this proposition, however. They believe that higher prices will spur more oil exploration and production.

Which group is right? Is the truth somewhere in between?

We believe that oil production outside OPEC will reach a peak between 2010 and 2015 and will then slowly decline. But within OPEC there are huge resources, particularly in the Middle East. The question is whether these resources can be translated into production, given current political, legal, and institutional barriers against international investment. We believe the answer to this question is "no."

So while global oil production may not reach a peak because of limited resources, it is likely to reach a peak because of intractable political problems in the key oil-exporting nations of the Middle East. For these reasons, global production may reach a peak some time between 2010 and 2020.

Meanwhile, the price of oil will stay up and will rise even higher unless consumption is significantly reduced.

A worker walks toward the Bohai Bay oilfield on the northeastern coast of China. Oil production is not insignificant in the Asia-Pacific region, but there appears to be limited potential for increasing production, or even maintaining current levels.
© REUTERS/China Daily/ Landov

The precise breakdown of petroleum products obtained from a barrel of oil varies to some extent according to the characteristics of the crude oil used and the sophistication of the refining process. Crude oil refined in Asia and the Pacific, for example, yields relatively high proportions of diesel and fuel oil, while crude oil refined in the United States yields a higher proportion of gasoline.

There are limits to how much the balance of petroleum products can be altered during the refining process, however. So even countries that produce and refine their own oil often need to meet their consumption requirements by selling some petroleum products and buying others. China is a good example. To maximize the production of diesel, which is in high demand, China produces a surplus of gasoline and a relatively limited supply of fuel oil. China has thus become the second largest fuel-oil importer in Asia after Singapore.

With economic development, the structure of energy consumption changes, and this affects demand for specific petroleum products. As incomes rise, individuals consume more electricity in their homes and more fuel for transportation (Figure 3.4). At the same time, economic activity shifts away from manufacturing toward the information and service sectors, and energy consumption in the industrial sector tends to taper off.

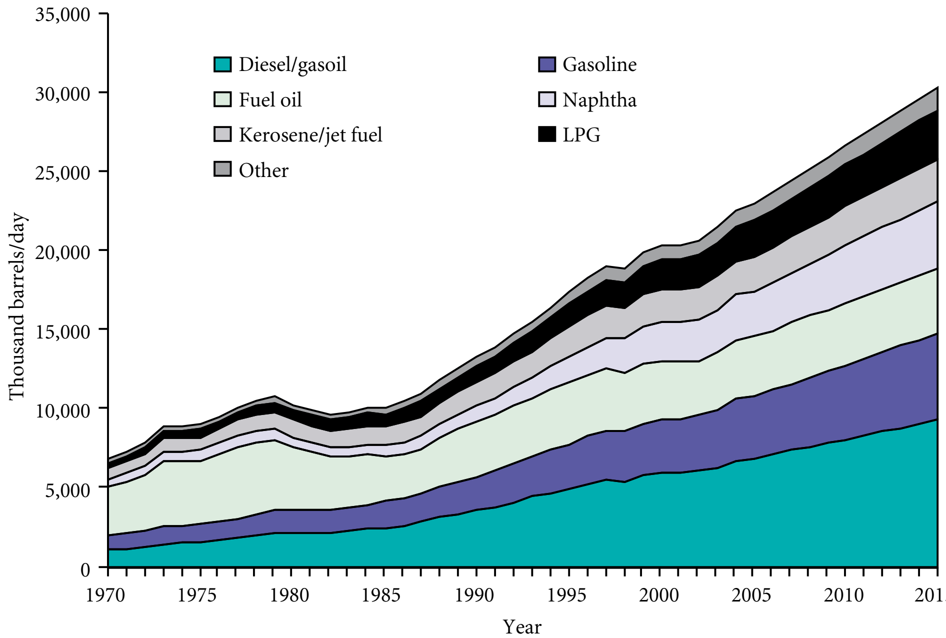
Changes in oil consumption in the Asia-Pacific region illustrate this shifting pattern of energy demand. The transport sector's share of overall oil consumption has been increasing steadily since the 1970s. As a result, the demand for transport fuels—diesel and gasoline—is growing more rapidly than the demand for other petroleum products (Figure 3.3). Looking toward the future, the total number of cars, trucks, and buses in Asia is expected to double every seven years. Demand for diesel and gasoline can be expected to grow at a similar rate.

Among other petroleum products, LPG is used mainly in the residential sector, and naphtha is used as feedstock to produce petrochemicals. The Asia-Pacific region has long been short of these two products, and growth in demand is strong. Demand is also strong for kerosene/jet fuel and for some specialized products such as lubricants (for the automobile industry), asphalt (for road construction), and petroleum coke (for aluminum and specialized steel production). Fuel oil, which is mainly used for power generation, industrial production, and as bunker fuel for ships, is in short supply, but demand growth is flat because fuel oil can be replaced in large part by other fuels such as coal and natural gas.

Apart from securing enough oil to meet rising demand, policymakers in Asia and the Pacific need to be concerned with national refining capacity and the overall regulatory environment for trade in oil and oil products. Today, countries in the region vary widely in their capacity to refine crude oil, and this affects their role in the international market for petroleum products. Among the countries that have oil refineries, capacity ranges from more than 6 million b/d in China to 5,000 b/d in Vietnam (Appendix Table 3.3).

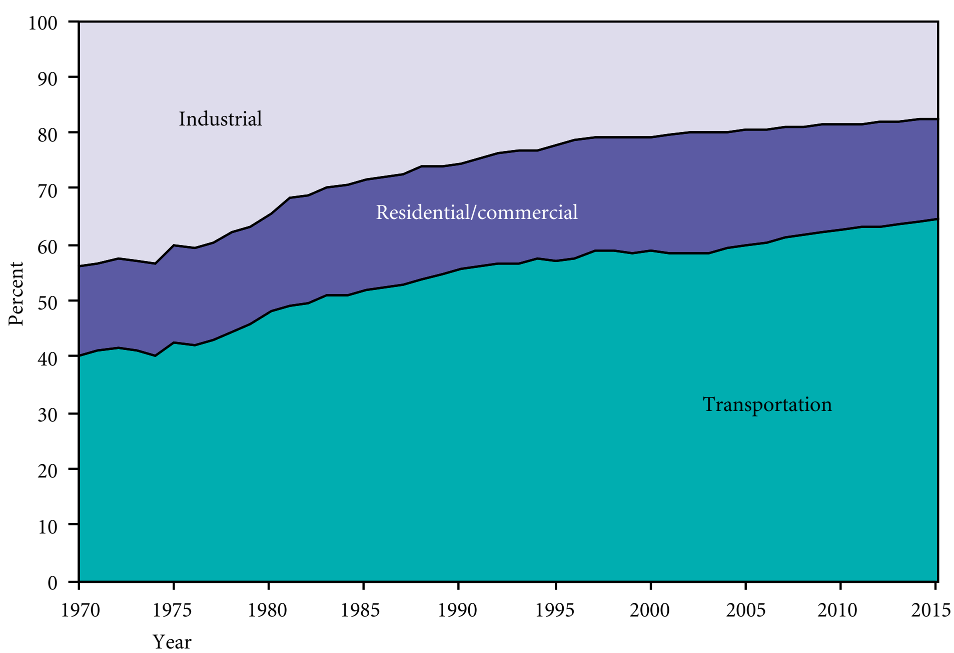
Some small countries do not have refineries at all and thus need to meet all domestic demand for petroleum products from imports. These are Bhutan,

Figure 3.3. Consumption of petroleum products in the Asia-Pacific region, 1970–2015 (thousand barrels per day: b/d)



Source: FACTS Global Energy (2006).
Note: Data for 1970–2005 are actual, data for 2006 are preliminary, and data for 2007–2015 are forecasts.

Figure 3.4. Share of petroleum-product consumption by the industrial, residential/commercial, and transportation sectors, Asia-Pacific region, 1970–2015



Source: FACTS Global Energy (2006).
Note: Petroleum products consumed in the transportation sector include gasoline, diesel, and kerosene/jet fuel. Data for 2007–2015 are forecasts.

Cambodia, Lao People's Democratic Republic (Laos), Mongolia, Nepal, and all Pacific Island nations. Others countries have petroleum refineries, but their output capacity does not meet domestic demand, either in terms of volume or standards or product mix. Countries that have domestic refineries but import more petroleum products than they export are Australia, China, Indonesia, Japan, Pakistan, the Philippines, and Vietnam (Appendix Table 3.4). By contrast, India, Singapore, South Korea, Taiwan, and Thailand refine more petroleum products than their domestic markets require and export more than they import.

Singapore plays a unique role in the regional market for petroleum products. Singapore's domestic demand is relatively small, but it possesses significant refining capacity. "Merchant" refineries in Singapore focus primarily on importing and exporting petroleum products. They have long supplied products to other countries in the region—and even on a modest scale to the United States—making Singapore a regional hub for the trade in petroleum products.

Singapore also possesses significant storage capacity. Apart from storing oil and petroleum products, traders can use Singapore's storage facilities to blend petroleum products to meet particular market specifications. It is therefore not surprising that Singapore tends to set the regional price for petroleum products. Singapore spot (FOB or free on board) prices are used as benchmarks for almost all the trade in petroleum products in the regional market.

Among large product importers, Japan and South Korea primarily import naphtha and LPG, mostly used as feedstock for their petrochemical industries. The largest product exporter is Singapore, but South Korean refineries also play an important role in supplying the regional market, followed by India, China, and Taiwan. China is a net product importer (mostly fuel oil) but exports a surplus of certain products (mostly gasoline).

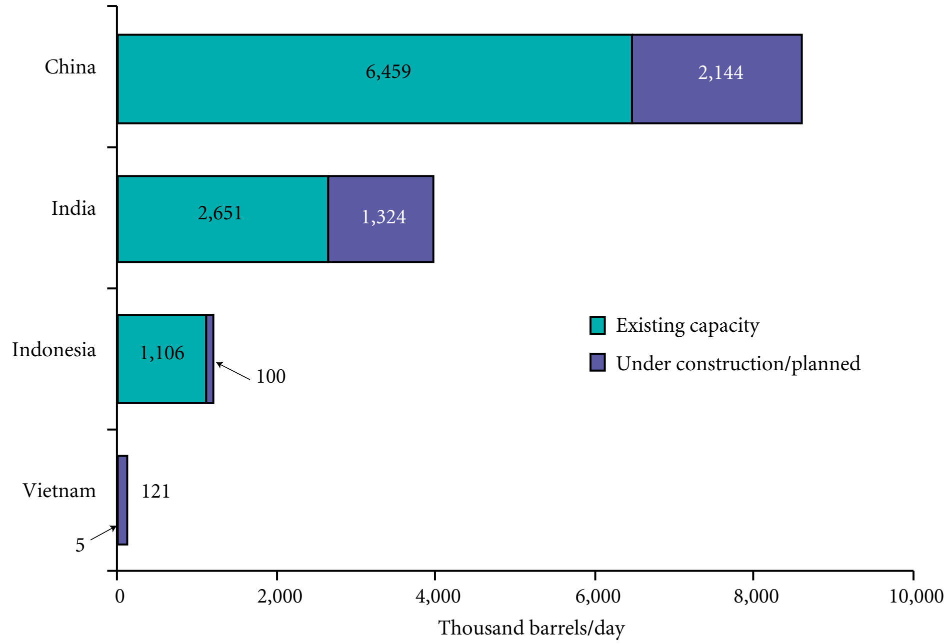
Future trade in petroleum products will depend, in part, on future plans for refinery capacity, especially in Asia's developing countries where domestic demand is increasing. Plans to expand the capacity of a nation's refineries may be based on security concerns, on economic considerations, or both.

Given China's rapidly growing domestic demand, it is not surprising that Chinese oil companies are planning to expand refining capacity significantly (Figure 3.5). Most countries or economies that have some extra capacity, such as Singapore, South Korea, Taiwan, and Thailand, are not planning to add more, at least at present.

India is an exception. Indian oil companies—both state owned and private—enjoy a level of government protection that gives them a competitive edge in international markets. Because they expect this situation to continue, refineries in India are expanding well beyond the needs of the domestic market. Indian refining capacity is expected to increase from 2.6 million b/d in mid-2005 to at least 3.9 million b/d by 2010 and possibly to much higher levels in the years beyond.

The decision to expand refining capacity depends on many factors, but the most important is profitability, as indicated by gross refining margins

Figure 3.5. Existing refinery capacity at the beginning of 2006 and expansion under construction or planned for 2006–2010: China, India, Indonesia, and Vietnam (thousand barrels per day: b/d)



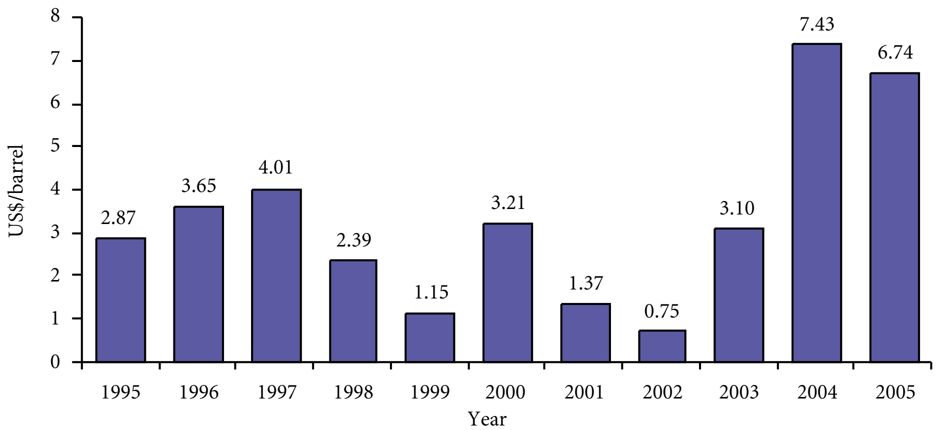
Source: FACTS Global Energy (2006).
Note: This figure only includes plans that are relatively firm. Most plans to add capacity by 2008 are fairly certain because additions are already at an advanced stage of planning or under construction. Plans to expand capacity beyond 2008 are less certain.

(Figure 3.6). Profit margins in the industry were at an all-time high in 2004 and remained high in 2005 and healthy in 2006, so future expansion may be greater than has been projected. In addition to China and India, Bangladesh, Pakistan, and Papua New Guinea are all considering expanding their refining capacity, and both Indonesia and Vietnam are considering expansions beyond the rather conservative estimates given in Figure 3.5.

Based on projected domestic demand and plans to increase refining capacity, India can be expected to increase its net exports of petroleum products over the next few years by more than four times (Appendix Table 3.4). Singapore should also continue its important role as an exporter. Projected exports from Taiwan and South Korea will continue to be larger than imports, while exports and imports will roughly balance in Thailand. China will add substantial refining capacity between now and 2010, but it will still be a net importer of fuel oil, diesel, and LPG, while its current surplus of gasoline will decline. All other countries in the region will remain net importers of petroleum products.

Although oil refineries are enjoying high profits today, a tendency toward overcapacity could severely reduce profitability in the future. This should be of concern to companies considering whether to invest in additional refining capacity and also to governments that have manipulated prices to support national refining industries. In addition to the expansion of capacity within the region, countries in the Middle East are also expanding their refineries with the aim of increasing exports of petroleum products.

Figure 3.6. Typical gross profit margins for oil refineries in the Asia-Pacific region, 1995–2005 (U.S. dollars per barrel)



Source: FACTS Global Energy (2006).
Note: Based on prices of Dubai crude—including cost, insurance, and freight (CIF)—in Singapore and prices of petroleum products (Singapore FOB) in a hypothetical, sophisticated refinery configuration.

Beyond 2010, markets for oil and petroleum products will probably be fully or largely deregulated in almost all countries of the region. Governments will be less likely to set prices artificially, and procurement will be based more directly on economic factors than is the case today. In this situation, countries that find themselves increasingly dependent on imported petroleum products will undoubtedly take steps to expand their refinery capacity. Countries with over-capacity due to a history of government price supports, such as India, may find themselves cutting back.

One factor that impedes international trade in refined petroleum products is the lack of agreement on product specifications. Until the late 1990s, quality standards for petroleum products varied widely among countries in the region, and a great deal of blending or upgrading was required to achieve the right specifications for various countries. At present, there is still a lack of international agreement, but several countries have made efforts to standardize and simplify their specifications. Although agreement on a single set of standards is unlikely in the foreseeable future, the improvements that have been achieved will facilitate the trade in refined petroleum products throughout the region.

Growing dependence on imported oil

The Asia-Pacific region leads the major oil-consuming regions of the world in terms of dependence on imported crude oil and petroleum products. In 2005, Asia and the Pacific imported 66 percent of the oil it consumed from outside the region. Dependence on imported oil is projected to grow, albeit slowly, over the next five years (Appendix Table 3.5). By 2010, the region's oil imports are projected to increase to 68 percent of total consumption.

Dependence on imported oil is most extreme in the highly industrialized economies of the region. Japan, Singapore, South Korea, and Taiwan import all of the oil they use (Appendix Table 3.1). By comparison, in 2005, the United States imported 58 percent of the oil it consumed. Countries in Asia and the Pacific at a much lower level of economic development are also highly dependent on imported oil. Bangladesh and the Philippines import more than 90 percent of the oil they consume, and Pakistan and Thailand import about 80 percent.

Even the region's major oil producers are net importers. In 2005, China was the largest oil producer in the region, but net imports accounted for 44 percent of Chinese oil consumption. India's net oil imports accounted for 73 percent of total consumption. Only Brunei, Malaysia, Papua New Guinea, and Vietnam were net exporters of oil (see Energy Insecurity Index).

Where does the imported oil come from? Today and for the foreseeable future, by far the most important source of oil for Asia and the Pacific is the Middle East. With its vast reserves and close geographic proximity, the Middle East can provide oil to the Asia-Pacific region at the lowest prices available. In 2005, 83 percent of the oil imported from outside the region came from the Middle East (Appendix Table 3.6). By contrast, the Middle East supplied only 24 percent of the oil imported into Europe and only 17 percent of the oil imported into the United States.

This dependence on the Middle East works in two directions. The Asia-Pacific region is by far the most important market for Middle-Eastern oil producers. In 2005, the Middle East exported a total of 19.8 million b/d of crude oil and refined products: Two-thirds of these exports went to Asia and the Pacific (BP 2006).

The Atlantic Basin—most notably West Africa—began to play a supplementary, but important, role in supplying oil to the Asia-Pacific region around 1995. Since 2000, Asian and Pacific countries have imported more than 1.5 million b/d of crude oil from Atlantic-Basin countries. This rise in imports has occurred even though crude oil from the Atlantic Basin tends to be more expensive than oil from the Middle East and the distance from the Asia-Pacific region is also greater, leading to higher shipping costs.

The trend toward expanding imports from the Atlantic Basin is likely to continue, primarily because of quality differences. Atlantic-Basin crude oil, which is predominantly low in sulfur (or "sweet"), is mixed with predominantly high-sulfur (or "sour") crude from the Middle East to meet increasingly strict environmental regulations. Refiners in the region import varying amounts of Atlantic-Basin crudes to maximize profitability as the price differential fluctuates between oil from the Atlantic Basin and the Middle East. A certain amount of low-sulfur crude is required to meet environmental standards, however, irrespective of price.

Another consideration relates to refinery capacity. Refineries in countries such as China and Indonesia were designed to process local crude oil, which is also low in sulfur. Many such refineries cannot process the high-sulfur Middle-Eastern crudes. These refineries will have to modernize, or they will be forced to import more crude oil from the Atlantic Basin as local oil production goes down.

Crude oil also comes to the Asia-Pacific region from Russia and Central Asia. Two pipeline projects have been designed to increase the region's access to oil from these sources. In May 2006, a 962-kilometer (km) (599-mile) pipeline became operational that brings oil from Kazakhstan to China. The pipeline's current capacity is 200,000 b/d. This pipeline is one component of a 3,000-km (1,864-mile) pipeline project designed to link China with the Caspian Sea. The full project is scheduled for completion in 2010, with capacity doubling to 400,000 b/d. Yet even at its full capacity, this pipeline will supply less than 10 percent of China's projected oil imports.

The Russian government is also planning to construct a pipeline to the Far East (see box), perhaps in the next decade, which will significantly raise the volume of Russian crude oil consumed in Asia and the Pacific. Even with a growing supply from this source, however, the Middle East will still be the primary source of oil for the region.

Despite efforts to diversify energy consumption away from oil and to diversify the region's oil supply away from the Middle East, the absolute amount of oil (including both crude oil and petroleum products) imported into the Asia-Pacific region from the Middle East is rising steadily (Wu 2002). By 2010, a projected 68 percent of all oil consumed in the region will be imported, and 76 percent of all imported crude oil will come from the Middle East.

One aspect of this large and growing dependence on oil from the Middle East is a high level of dependence on sea transport through the Malacca Strait. Today, more than 90 percent of oil imported into the Asia-Pacific region is transported by sea tanker through this narrow channel that separates peninsular Malaysia from the Indonesian island of Sumatra. The importance of this one sea lane raises concerns about possible supply disruptions due to accidents, piracy, or terrorism. Even if current plans for pipeline construction come to fruition, the large majority of imported oil will continue, for the foreseeable future, to reach the Asia-Pacific region by this one route.

Singapore is close to the Malacca Strait, heightening concern that this important hub for oil trade in the region might also be the target of a terrorist attack. Any major attack on oil tankers in the Strait or on refineries or storage facilities in Singapore would set off a severe spike in oil prices, both in the region and around the world.

Oil currently supplies 35 percent of the Asia-Pacific region's energy needs. With large populations, rapid economic growth, and domestic and international pressure to reduce the use of coal on environmental grounds, the demand for oil can only go up. Policymakers face the daunting task of balancing this escalating demand against the reality of limited oil supplies within the region and the security risk of overdependence on one shipping lane and on supplies from the volatile Middle East.

As early as the 1970s, Japan expressed interest in the construction of a pipeline from oil fields within the Soviet Union to the Pacific coast. From a coastal location in the Russian Far East, it would be relatively inexpensive to ship oil to Japan. The objective was to reduce Japan's dependence on oil imports from the Middle East. At the time, however, Cold War politics made the plan unrealistic.

After the breakup of the Soviet Union, Russia was eager to expand oil exports to Asia. In 2003, after nearly a decade of negotiation, the state-owned China National Petroleum Corporation (CNPC) and the private Russian oil company, Yukos, signed a contract to build a 2,400-km (1,491-mile) pipeline from the Angarsk oil field in Russia to Daqing in northeastern China (see map). In the meantime, supported by the Japanese and Russian governments, the Russian state-owned transportation company, Transneft, came up with an alternative proposal for a pipeline from the Angarsk field to Perevoznaja Bay on the Pacific coast, with easy access to Japan.

At an estimated length of 4,000 km (2,485 miles), a pipeline from Angarsk to Perevoznaja Bay would be considerably longer and more expensive than a pipeline from Angarsk to Daqing. And ultimately, the pipeline will be longer still because the Russian government rejected initial proposals on environmental grounds since the pipeline would pass too close to Lake Baikal.

Proposed route of oil pipeline from Taishet, northwest of Lake Baikal, to Perevoznaja Bay on the Pacific coast of the Russian Far East, with a spur line to Daqing in northeastern China. Source: *EIA (2006).*

The latest plan, approved by the Russian government, is to originate the pipeline at Taishet—northwest of Lake Baikal—rather than at the Angarsk oil field just south of the lake. According to this plan, the primary pipeline will extend to Perevoznaja Bay, although a branch line to China may also be built. Projected costs keep going up, but the Russian government favors the longer route for several reasons quite apart from the rivalry between Japan and China. A pipeline to Perevoznaja Bay would stimulate economic development in the Russian Far East, which is a goal of both national and local governments. An additional political factor is the Putin administration's criticism of Yukos, which has been targeted for tax evasion and other alleged illegal activities. Because of the longer distance and difficult terrain, the new pipeline plan is expected to cost up to US$16.5 billion—more than five times the projected cost of an Angarsk-Daqing pipeline and three times the cost of a pipeline from Angarsk to Perevoznaja Bay.

The proposed pipeline would have a capacity to transport 1.0 to 1.6 million b/d. At present, oil production near Taishet is not sufficient to support this capacity. Apart from construction of the pipeline, additional billions of dollars will be required to explore and develop enough production capacity to provide this much oil for export. Nevertheless, and after much delay, Russia is moving closer to building the Taishet pipeline to the Pacific coast with a branch line to China (Milov 2005).

CHAPTER FOUR

Natural Gas

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Jeffrey G. Brown

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Workers repair a natural-gas pipeline in southwestern China's Chongqing municipality. Expanding the use of natural gas will require expensive investments in infrastructure but could lower dependence on Middle-Eastern oil.
© REUTERS/China Daily/Landov

Today, the Asia-Pacific region uses relatively little natural gas and produces nearly as much as it consumes (Figure 4.1 and Appendix Table 4.1). This situation is poised to change, however, as Asian and Pacific countries make plans to expand their use of natural gas dramatically. The motivation is twofold: to reduce dependence on imported oil and to lower environmental pollution from the use of coal. Thus, the expanded use of natural gas is seen as a key strategy—on two fronts—to enhance energy security in the region.

Historically, natural gas was viewed by the energy industry as an "ugly duckling," compared with its more versatile brother, oil. In fact, a number of oil producers simply treated natural gas as a byproduct and burned it off (a process called "flaring") because the cost of processing the gas and transporting it to distant markets was greater than its commercial value.

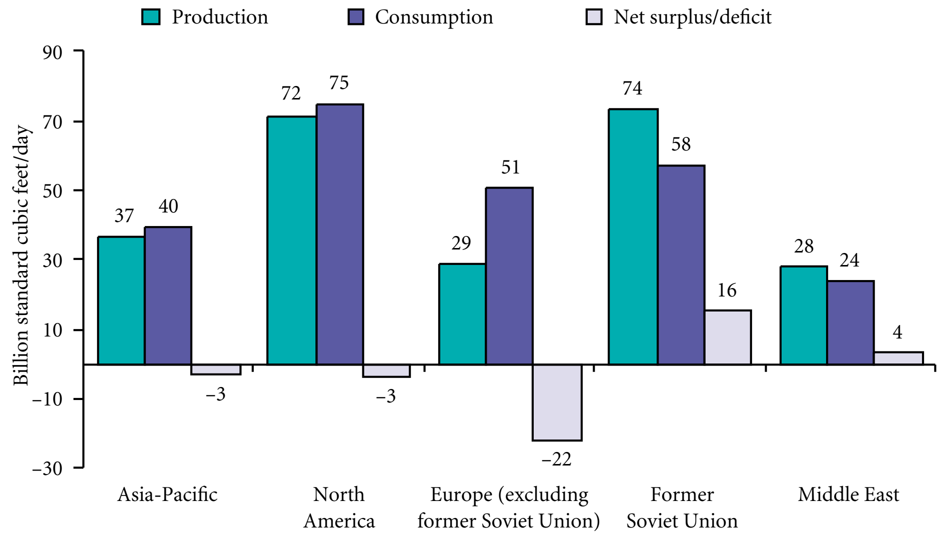
Improvements in processing and transport over the past 30 years have allowed natural gas to penetrate markets that were previously inaccessible because of distance or geographic barriers. Higher efficiency and lower investment and operating costs have reduced market barriers and increased the competitiveness of natural gas compared with other fuels, such as oil and coal. Thus, at a time when demand is rising, the supply of natural gas is also increasing.

Limited development of pipelines

Natural gas is currently marketed in two forms. It is either distributed in its original, gaseous state by pipeline, or it is processed into liquefied natural gas (LNG) and transported by ocean tanker. A third technology is also emerging based on transporting compressed natural gas by ocean tanker, but this approach has yet to be proven commercially. Within the Asia-Pacific region, the distance between supply centers (such as Indonesia) and demand centers (such as Japan) coupled with geopolitical concerns—which often take precedence over economics—has inhibited the development of international pipelines. In the region as a whole, only 10 international pipelines operate, all in Southeast Asia (see box), transporting natural gas to destinations in Malaysia, Singapore, and Thailand. Another pipeline connects the Yacheng gas field on China's Hainan Island with consumers in Hong Kong.

As the Southeast-Asian example illustrates, there is interest in building natural-gas pipelines in the region, but governments must overcome a host of contentious issues. Over the years, a variety of pipeline projects have been proposed, only to become bogged down by disagreements over pricing and security

Figure 4.1. Natural-gas production, consumption, and surpluses/deficits in major regions of the world, 2005 (billion standard cubic feet per day: scf/d)



Sources: BP (2006); FACTS Global Energy (2006).

of supply. Table 4.1 lists international pipelines currently proposed in the region.

Disputes over pricing pose a major stumbling block. A variety of pricing mechanisms exists for piped natural gas, with some countries insisting on prices that are generally considered below market rates. Some governments, including India and China, mandate lower prices for certain economic sectors—such as agriculture or industry. This type of pricing policy acts to discourage investment in international pipelines because it becomes impossible for developers to secure an adequate rate of return on their investments.

Even if it is agreed that natural gas should be priced at a market rate, the prices of competing fuels—which help to determine the market price for gas—can serve as a source of contention. For example, northeast China would like to import gas from the Kovykta field in eastern Russia to fuel industrial enterprises and power plants. Today, these sectors are fueled predominantly by coal, and the Chinese want prices for natural gas similar to the low prices that they currently pay for coal. The Russians have refused, however, pointing out that they receive much higher prices for natural gas in the European market. They maintain that a pipeline project is not viable at the price level suggested by the Chinese. Meanwhile, South Korea would like to extend a pipeline from Russia to their consumers but cannot move forward without China.

Emerging market for liquefied natural gas (LNG)

LNG is primarily methane that has been cooled to minus 160 degrees centigrade (C)—equivalent to minus 259 degrees Fahrenheit (F)—and stored in insulated containers. In this liquid state, it occupies less than 0.16 percent of its original volume. The liquefied gas is transported by ocean tanker to a receiving

The Association of Southeast Asian Nations (ASEAN), established in 1967, includes member countries Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Laos), Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. One primary objective of the Association is to accelerate economic growth in the region through joint projects.

In keeping with ASEAN's development goals, member countries agreed in 1997 and again in 2002 to connect and expand existing pipelines into a Trans-ASEAN Gas Pipeline (TAGP). The expanded system of pipelines is expected to stretch from 4,500 to 5,500 kilometers (km) (2,800 to 3,400 miles). The goal is to encourage member countries to explore for natural gas and to improve energy security in the region.

The first pipeline that was constructed connected the Kerteh gas field in Malaysia to Singapore. This was followed by pipelines from the Yadana and Yetagun fields in Myanmar to the Thai border and on to Ratchaburi in Thailand; from fields in Indonesia to Singapore and Malaysia; and from the Commercial Agreement Area (CAA) between Malaysia and Vietnam to Malaysia. Most recently, pipelines have been completed linking the offshore Joint Development Area (JDA) between Thailand and Malaysia with Thailand's Songkla Province and the area in Malaysia that faces the Gulf of Thailand.

Existing international pipelines for natural gas in Southeast Asia, 2005

From	To	Field	Buyer	Length (km)	Capacity (million scf/d[a])	First year in operation
Malaysia	Singapore	Kerteh	Senoko Power	[b]	160	1992
Myanmar	Thai border	Yadana	EGAT[c]	409	650	1999
Thai border	Thailand (Ratchaburi)	Yadana/ Yetagun	EGAT[c]	240	950	1999
Myanmar	Thai border	Yetagun	EGAT[c]	300	300	2000
Indonesia	Singapore	West Natuna	SembCorp	640	1,000	2001
Indonesia	Malaysia	West Natuna	Tenaga Nasional	96	600	2002
Indonesia	Singapore	Sumatra	PowerGas	500	350	2003
CAA[d]	Malaysia	CAA[d]	Petronas	100	300	2005
JDA[e]	Thailand	JDA[e]	PTT[f]	267	1,020	2005
JDA[e]	Malaysia	JDA[e]	Petronas	98	750	2005

Source: FACTS Global Energy (2006).
[a] Standard cubic feet per day.
[b] Part of Malaysia's 714-km Peninsular Gas Utilization (PGU) Project pipeline, phase 2.
[c] Electricity Generating Authority of Thailand.
[d] Commercial Agreement Area between Malaysia and Vietnam.
[e] Joint Development Area between Thailand and Malaysia.
[f] PTT Public Company Limited, Thailand.

Pipeline development has generally been slow because projects face a number of hurdles. Among the main issues are financing, pricing, taxation, and marketing. For example, who will maintain the pipeline, and who will have the power to tax the gas passing through the system? There must also be agreement on national legal and regulatory frameworks and the respective roles of the public and private sectors.

Local residents and environmental groups in the southern Thai town of Chana carry a mock natural-gas pipeline in a protest march against a joint pipeline project between Thailand and Malaysia.
© REUTERS/Jason Reed/Landov

Table 4.1. Proposed international pipelines for natural gas in the Asia-Pacific region, 2005

From	To	Field	Length (km)	Capacity (million scf/d[a])	Likelihood of completion
Bangladesh	India	Bibiyana/Sangu	1,400	1,000	Unlikely
CAA[b]	Vietnam	CAA[b]	235	270	Likely
China	Hong Kong	Guangdong LNG	<100	200	Likely
Iran	India	Assaluyeh	2,600	1,000	Uncertain
Malaysia	Philippines	Sabah	500	350	Unlikely
Myanmar	India via Bangladesh	A-1 (offshore Myanmar)	1,500	1,200	Uncertain
Papua New Guinea	Australia	Hides/Kutubu/ Moran	3,250	600	Likely
Russia	Japan	Sakhalin-1	1,950	800–1,000	Unlikely
Russia	China (Beijing)	Sakhalin-1	2,200	1,000	Unlikely
Russia	China (Shanghai)	West Siberia	6,500	3,200	Unlikely
Russia	China/ South Korea	Kovykta (Irkutsk)	4,900	3,000	Likely
Russia	China/Japan	Yakutsk	4,800	2,000	Unlikely

Source: FACTS Global Energy (2006).
[a] Standard cubic feet per day.
[b] Commercial Agreement Area between Malaysia and Vietnam.

terminal and then piped to nearby storage tanks. When it is needed, it is piped to a regasification facility where it is heated and converted to its gaseous form. It is then piped into a distribution network or to a power plant.

Today's expanding international trade in LNG can be attributed in large part to the technical and economic problems associated with building and maintaining long-distance pipelines. Generally, it is cost-effective to transport natural gas by pipeline up to a distance of 3,500 km (2,175 miles) overland or 1,800 km (1,118 miles) under the sea. For longer distances, conversion to LNG and shipping by tanker is more economical. Conversion to LNG is also advantageous in situations where geography or politics raises the cost of pipeline construction.

Compared with oil refining and transport of oil in ocean-going tankers, LNG transportation and processing have been remarkably free of accidents. LNG has been transported in ocean-going vessels and LNG regasification and storage facilities have operated in populous cities for 40 years without a single serious accident on land or at sea.

The development of LNG technology has enabled producers to market natural gas over much longer distances than in the past, contributing to today's rapid rise in the international gas trade. Lacking gas fields near their primary centers of consumption, many countries in Asia and the Pacific use a much higher proportion of LNG than countries elsewhere of the world. Today, LNG accounts for about one-third of gas consumption in the region, compared with 7 percent of gas consumption in the world as a whole.

Production and consumption in the Asia-Pacific region

Asian and Pacific countries play a major role in the world market for natural gas, both as producers and consumers, especially in the market for LNG. As of 2005, the region held 501.5 trillion cubic feet of proven natural-gas reserves, or about 8 percent of the world total, which stood at 6,337.4 trillion cubic feet (BP 2006). During the year, Asian and Pacific countries consumed 39.6 billion standard cubic feet per day (scf/d) of natural gas. Net imports were 3.5 billion scf/d, about 9 percent of total consumption. Between 2005 and 2015, natural-gas consumption is expected to increase by an annual average of 5.3 percent (Appendix Table 4.2), reaching 66.6 billion scf/d in 2015 (FACTS Global Energy 2006). Over the same period, net imports are projected to rise to 11.7 billion scf/d, or 18 percent of total consumption (Appendix Table 4.1).

In 2005, the region's four largest natural-gas producers were Indonesia, Malaysia, China, and Australia (Appendix Table 4.3). China's natural-gas production was nearly sufficient to supply domestic demand, while Indonesia, Malaysia, Australia, and Brunei Darussalam were the largest natural-gas exporters in the region. These four countries produced nearly twice as much LNG as the three producers in the Middle East—Qatar, Oman, and Abu Dhabi (Table 4.2).

Producers in the Middle East are catching up, however. Qatar is already an important exporter of LNG and has large additional projects under construction that will become operational by 2008 or 2009. In the Asia-Pacific region, only Australia is currently planning or constructing new production facilities on a comparable scale. Between now and 2010, the Middle East will go a long way toward closing the gap in LNG export capacity.

Japan is the largest consumer of natural gas in the region, followed by China, Indonesia, Malaysia, and Pakistan (Appendix Table 4.3). Japan and South Korea are the largest importers, followed by Taiwan. India began importing LNG from Qatar in 2004. Although China meets most of its modest natural-gas needs (3 percent of total commercial energy consumption) from domestic production, the Chinese began importing LNG from Australia in 2006 and will start importing from Indonesia in 2009. In Southeast Asia, Malaysia, Singapore, and Thailand import natural gas through pipelines from neighboring countries, and it is likely that the Philippines, Singapore, and Thailand will begin importing LNG by 2015.

In the Asia-Pacific region as a whole, the most important use of natural gas

Table 4.2. Actual or projected capacity of liquefied natural gas (LNG) production facilities that are operating, under construction, or under consideration in the Asia-Pacific region and the Middle East, January 2006 (million tonnes per annum: t/a)

Asia-Pacific	Production capacity (million t/a)	Middle East	Production capacity (million t/a)
Operating		**Operating**	
Australia (Darwin)	3.5	Abu Dhabi	5.7
Alaska (Kenai)	1.4	Oman	7.3
Australia (NWS)	7.8	Qatargas	9.6
Australia NWS Train 4	4.4	Qatar (RasGas)	6.6
Brunei	7.2	Qatar (RasGas II Train 3)	4.7
Indonesia (Bontang)	22.6	Qatar (RasGas II Train 4)	4.7
Indonesia (Arun)	6.8	Oman (Train 3)	3.7
Malaysia (Satu)	8.1	Subtotal	42.3
Malaysia (Dua)	7.8		
Malaysia (Tiga Train 1)	3.7		
Malaysia (Tiga Train 2)	3.7		
Subtotal	77.0		
Under construction		**Under construction**	
Australia (NWS) T5	4.4	Qatargas II (Train 4,5)	15.6
Indonesia (Tangguh)	7.8	Qatargas III (Train 6)	7.8
Peru	4.0	Qatargas IV (Train 7)	7.8
Russia (Sakhalin II)	9.6	Qatar (RasGas II Train 5)	4.7
Malaysia (Dua Debottleneck)	1.3	Subtotal	35.9
Subtotal	27.1		
Under consideration		**Under consideration**	
Australia (Browse)	10.0	Iran	25.0
Australia (Gorgon)	10.0	Qatar (RasGas III Train 6,7)	15.6
Australia (Ichthys)	6.0	Yemen	6.7
Australia (Pilbara)	6.0	Subtotal	47.3
Australia (Pluto)	5.0		
Australia (Sunrise)	5.3		
Brunei (Train 6)	4.0		
Indonesia (Pandang)	1.6		
Subtotal	47.9		
Total	152.0	**Total**	125.5

Source: FACTS Global Energy (2006).
Note: Middle-Eastern projects under construction or consideration are expected to target primarily consumers in Europe and the United States.

Natural gas in its gaseous state cannot be weighed, so it is measured in terms of volume. In the United States, it is measured in standard cubic feet (scf), while in other parts of the world, it is measured in cubic meters (m^3). As a liquid, liquefied natural gas (LNG) can be weighed, and it is measured in tonnes, with one tonne equal to 1,000 kilograms. The price of natural gas, however, is often quoted in British thermal units (Btu), which is essentially a measure of heat. Measurement in Btus allows comparison with other hydrocarbon fuels such as oil and coal. The table gives the factors used to convert among these different measures.

Conversions between different measures of natural gas

	To			
From	Tonnes (LNG)	Cubic meters (m^3)	Standard cubic feet (scf)	Million British thermal units (Btus)
1 tonne (LNG)	1	1,350.0	47,675	51.49
1 m^3	0.0007407	1	35.315	0.03532
1 million scf	20.9752	28,316.6	1,000,000	1,080.0
1 million Btus	0.0194	28.313	925.92593	1

Liquefied natural-gas (LNG) storage tanks (upper right) near the chimney of Tokyo Electric Power Company's generating plant in Futtsu City, Japan. Japan and South Korea are the largest natural-gas importers in the region. © Michael Caronna/ Bloomberg News/Landov is to generate electricity (Figure 4.2). There is some variation among individual countries, however. In South Korea, the residential and commercial sector leads LNG consumption, primarily for heating in the winter. In India, the industrial sector accounts for a substantial portion of consumption because LNG is used to produce urea-based fertilizer.

There will be a modest increase in the use of natural gas in the transport sector as governments in some countries begin requiring buses, taxis, and other modes of public transportation to use compressed natural gas (CNG) in an effort to alleviate urban air pollution. India has taken the lead in this area, with recent legislation stipulating that buses and taxis in the capital city of Delhi switch to CNG, and in Seoul, South Korea, the government is promoting the use of CNG in buses. By 2015, however, the transportation sector will still only account for about 1 percent of natural-gas consumption in the region. Most future growth in consumption will be in the power sector.

Globalization of the natural-gas market

Until recently, the market for natural gas generally functioned at the regional level, with limited interaction between regions. With the emergence of multiple LNG supply sources, however, and growing demand in the enormous U.S. market, regional markets are likely to become more interdependent.

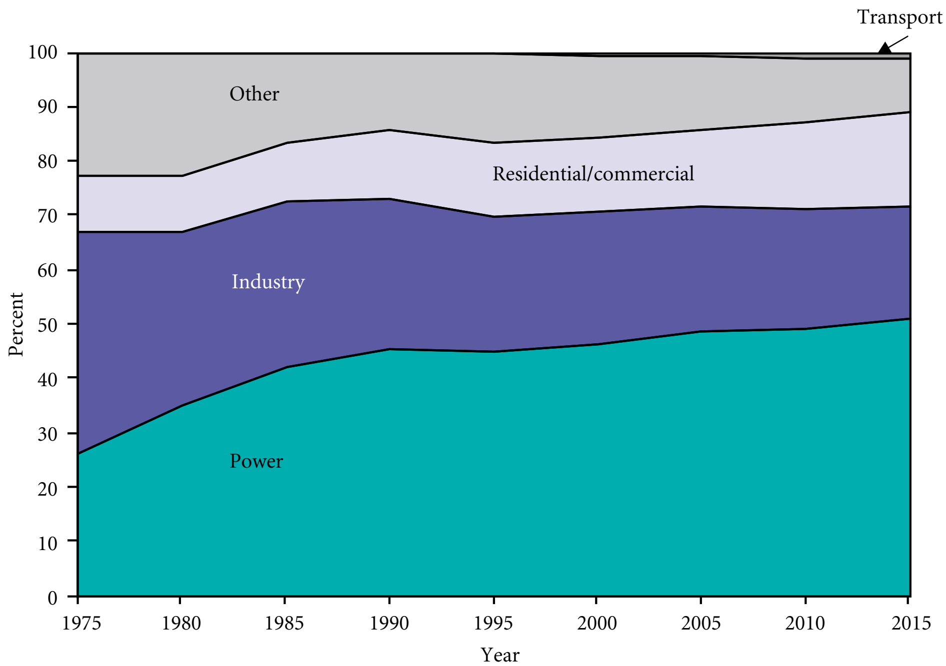
In 2005, the worldwide trade in LNG was 143 million metric tons (tonnes)—representing an 8-percent increase in just one year above 2004 levels. The Asia-Pacific market accounted for 92 million tonnes, or 64 percent of global trade. One of the most important factors contributing to growth of international trade, however, is the rapidly expanding U.S. market. Between 2002 and 2003, LNG imports more than doubled in the United States. This trend is expected to continue as domestic production and piped gas from Canada plateau over the next decade or even decline. LNG consumption in the United States is projected to increase from 13.0 million tonnes in 2005 to 78 million tonnes in 2015 and 87 million tonnes in 2025 (EIA 2006).

In 2005, more than 95 percent of LNG imported into the United States came from the Atlantic Basin—Trinidad, Algeria, Egypt, and Nigeria—while the balance came from the Middle East and the Asia-Pacific region. However, LNG imports from the Middle East are increasing rapidly. By 2010, the region is projected to capture nearly 50 percent of the U.S. market.

Today there are only five receiving and processing terminals for LNG in the United States, with a total capacity of 40 million tonnes per annum. All five terminals are located on the East Coast or the Gulf of Mexico. The Federal Energy Regulatory Commission (FERC) has approved expansion of some of these terminals and construction of four new receiving terminals on the Gulf Coast.

Plans for new terminals have also been proposed for the West Coast of the United States, where they would be positioned to import LNG from Asia and

Figure 4.2. Trends in natural-gas consumption in the Asia-Pacific region by economic sector, 1975–2015 (percent)



Source: FACTS Global Energy (2006).
Note: "Other" includes agricultural use, oil- and gas-field use, and other non-specified uses. It does not include distribution losses.

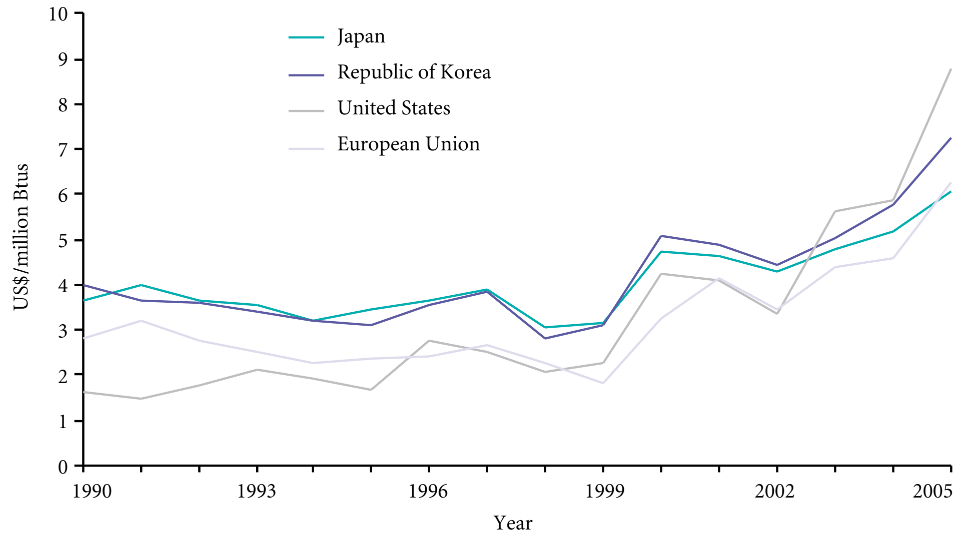
the Pacific. In addition, new terminals have been proposed in Canada, Mexico, and the Bahamas, which would serve the U.S. market. Although a number of these proposals will undoubtedly fail, adding up all the proposed capacity gives an indication of just how strong the U.S. market for LNG is perceived to be. If all of the proposed expansions and new terminals are built, the United States will have the capacity to import more than 400 million tonnes of LNG per annum—roughly triple today's total production capacity in the entire world.

Changing market conditions

Natural-gas prices in Asia and the Pacific have generally been determined by long-term contracts rather than by supply and demand. When many of today's existing contracts were signed, the market was still emerging, and producers needed high prices to secure financing for construction of infrastructure. At the same time, the largest consumers in the region—Japan and South Korea—were interested in natural gas to diversify energy sources and to improve energy security and were less concerned about cost. As a result, they generally ended up paying higher prices than consumers in the United States or Europe (Figure 4.3). This situation has changed in the past two years, however, as the market for natural gas has become more globalized and prices have gone up in the United States.

Beginning in the mid-1980s, a pricing scheme was introduced for LNG in

Figure 4.3. Natural-gas prices in Japan, the Republic of Korea, the United States, and the European Union, 1990–2005 (U.S. dollars per million British thermal units: Btu)



Source: FACTS Global Energy (2006).

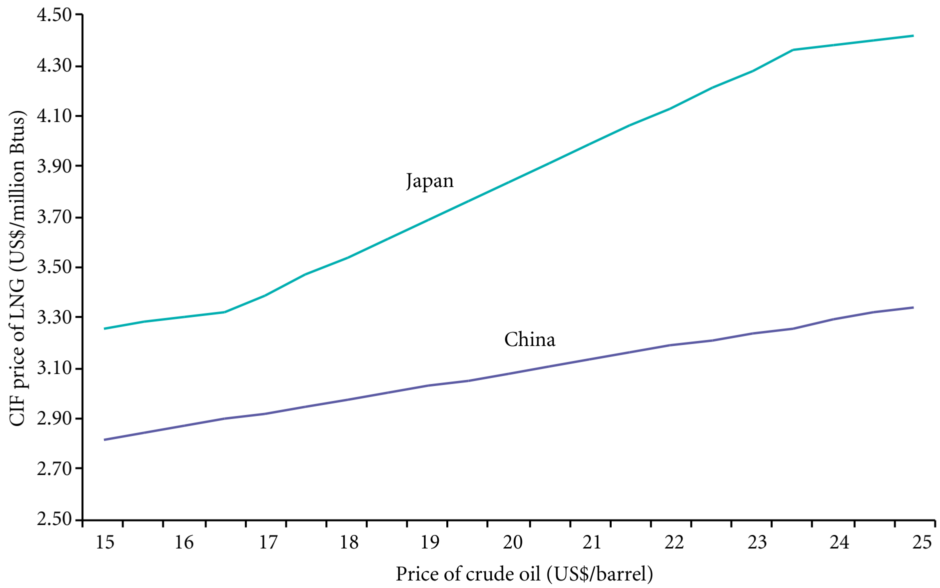
Asia and the Pacific based on the price of oil. The Japanese devised this pricing formula, which starts with the average monthly price of Japan's crude-oil imports. Although this formula has served as the industry standard for 20 years, the close linkage with oil prices seems increasingly inappropriate because natural gas typically no longer competes with oil as a fuel for the power sector. Because oil prices tend to be volatile, the link to oil prices also introduces a degree of volatility in the LNG market.

Over the years, some LNG buyers tried to change the pricing structure and other aspects of sales contracts, but demand tended to be greater than supply, which weakened their bargaining position. More recently, however, a number of new supply projects were proposed in the region, and production of LNG also increased in the Middle East. This new situation offered an opportunity for a buyer to bargain for better terms and lower prices, and the first buyer to take advantage of this opportunity was China.

Australia's Northwest Shelf (NWS) consortium began deliveries of LNG to Guangdong, China, in May 2006, according to a contract negotiated in September 2002 that reflected the changing market forces. The Chinese were able to change a number of previously standard LNG contract clauses, including a change in the pricing formula that is less closely linked to crude-oil prices and thus reduces price volatility. China also secured prices that were markedly lower than existing contracts between the Australian consortium and Japan (Figure 4.4).

The pricing formula that China negotiated with Australia's NWS surprised many in the LNG industry, especially the Japanese, who were paying substantially more for the same natural gas. The Japanese buyers' consortium helped start up the NWS project in the late 1980s, and the Japanese were, until recently, the project's sole customer for LNG. After the Chinese received a significant

Figure 4.4. Prices negotiated by Japanese and Chinese buyers for LNG from Australia's Northwest Shelf (NWS) consortium, based on price of oil (U.S. dollars per million British thermal units: Btu)



Source: FACTS Global Energy (2006).
Note: All natural-gas prices are CIF (cost, insurance, freight), which is the full price including delivery costs.

price reduction, the Japanese buyers also took a harder line in price reviews, and they too were able to achieve some concessions from NWS.

Overall, Japanese buyers have become notably more assertive when renewing contracts. For one thing, Japan's aging population and changing social and industrial structure make it difficult to predict demand, and as a result, Japanese buyers are reluctant to commit themselves to inflexible long-term contracts. At the same time, a number of current LNG exporters have amortized their initial investments and are no longer required by lenders to insist on inflexible 15–25 year contracts to pay back construction costs.

Thus, the market is increasingly characterized by a combination of long-term and short-term/spot contracts. "Take-or-pay" clauses, which required buyers to either take delivery or pay a specified amount (typically 90–95 percent of the contract value), are also being relaxed. These changes place newer production projects, which are still paying back development costs, at a competitive disadvantage.

Contracts are becoming more favorable to buyers in other ways. Most existing contracts, for example, limit the buyers' ability to resell natural gas that they do not need themselves. Recently, buyers have begun pushing for more flexible terms, called "destination clauses." Contracts like the agreement between ConocoPhillips's Bayu-Undan operation, offshore from Timor-Leste, and Tokyo Electric Power Company (TEPCO)—in which TEPCO gets a share of the profits when gas is resold—will likely become more common in the future.

Another improvement in flexibility favors buyers with strong seasonal patterns of use. For example, the Korea Gas Corporation's (KOGAS) medium-term contracts with Australia's NWS and Malaysia Liquefied Natural Gas (MLNG) Tiga are heavily weighted toward winter delivery. This is an important concession, considering that about 70 percent of Korea's annual LNG consumption occurs between October and March.

Some buyers are asserting more control over the market by taking charge of shipping. TEPCO—which is Japan's largest LNG importer, accounting for more than 33 percent of the country's total imports—has started using its own vessels to import some of its LNG supply. TEPCO's first vessel became operational in late 2003, and its second vessel became operational in 2006. By the end of 2006, Osaka Gas had three operational vessels, and Tokyo Gas had four.

Japan's successful push for increased flexibility, combined with the low prices achieved by the Chinese, supported a more flexible contract structure throughout the region. The market situation that favored buyers has turned out to be short-lived, however. By 2005/2006, the huge increase in LNG consumption in the United States, combined with limited supplies, worked to transform the global situation from a buyer's to a seller's market.

This shift has had a particularly unfavorable impact on the Chinese, who planned to double their natural-gas consumption by 2010. Buoyed by the low prices they obtained in 2002, Chinese buyers held out for low prices in the most recent round of contract negotiations. As a result, the Japanese were able to scoop up most of the remaining volume, and Chinese buyers faced a major loss of supply.

Market trends and forecasts

The expected growth of LNG imports into the United States could potentially alter patterns of trade on a global level. Historically, LNG producers in the Atlantic Basin have supplied Europe and North America, and Middle-Eastern and Asia-Pacific producers have primarily supplied Asia. In recent years, however, Middle-Eastern exporters such as Oman and Qatar have shown that it is economically feasible to export LNG to the United States, given high prices in the U.S. market and improved economies of scale that producers have been able to achieve at their liquefaction plants. Successful completion of planned receiving terminals on the U.S. West Coast would likely draw LNG from Asia-Pacific suppliers as well.

Over the coming decade, the LNG market is set to grow dramatically and to become much more interconnected at the global level. At a time when imports are increasing exponentially in the United States, China and India are also on a path toward massive new imports of LNG. While this trend toward increased consumption could be advantageous for producers in Asia and the Pacific, consumers in the region could find available supplies shrinking, especially if LNG prices in the United States remain high.

Alternatively, increasing exports of LNG to the United States could expand trade options and improve profitability, benefiting the entire market. Projects supplying South Korea, for example, could sell excess LNG to the United States in the summer months when Korean demand is low. Yet overall, with the United States emerging as a major LNG importer, sellers are less prepared to make concessions to potential buyers, and prices are moving toward all-time highs. The price concessions and favorable contractual terns that Asia-Pacific consumers were able to negotiate over the past few years are fast disappearing.

In principle, expanding the use of natural gas offers one of the best available policy options for lowering dependence on Middle-Eastern oil and improving the environmental impact of power generation. Yet intense competition for supplies and record high prices, triggered by escalating demand in the United States, pose significant challenges for policymakers in Asia and the Pacific.

Sikh families board a special train in Amritsar, India, to visit pilgrimage sites in Pakistan. Such cooperation between the two countries is limited. There have been discussions, but little progress, toward building a natural-gas pipeline from Iran through Pakistan to India.
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CHAPTER FIVE

China and India

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With huge populations and rapidly developing economies, China and India play a critical role in global energy markets. Both countries are among the largest and fastest-growing energy consumers in the world. Looking toward the future, both countries need to balance growing demand for energy against limited domestic supplies and rising dependence on imports. With heavy use of coal for industry and power generation and increasing use of oil for motor vehicles, both countries also face serious environmental challenges.

Policymakers in China and India have been concerned for some time about securing sufficient energy to fuel economic growth and meet the rising expectations of their large populations. To supply these needs, both countries have limited domestic reserves of fossil fuels, particularly of oil and natural gas (Figure 5.1). In recent years, rising energy prices and growing dependence on imports from the Middle East have brought concerns about energy security to the forefront of the policy agenda.

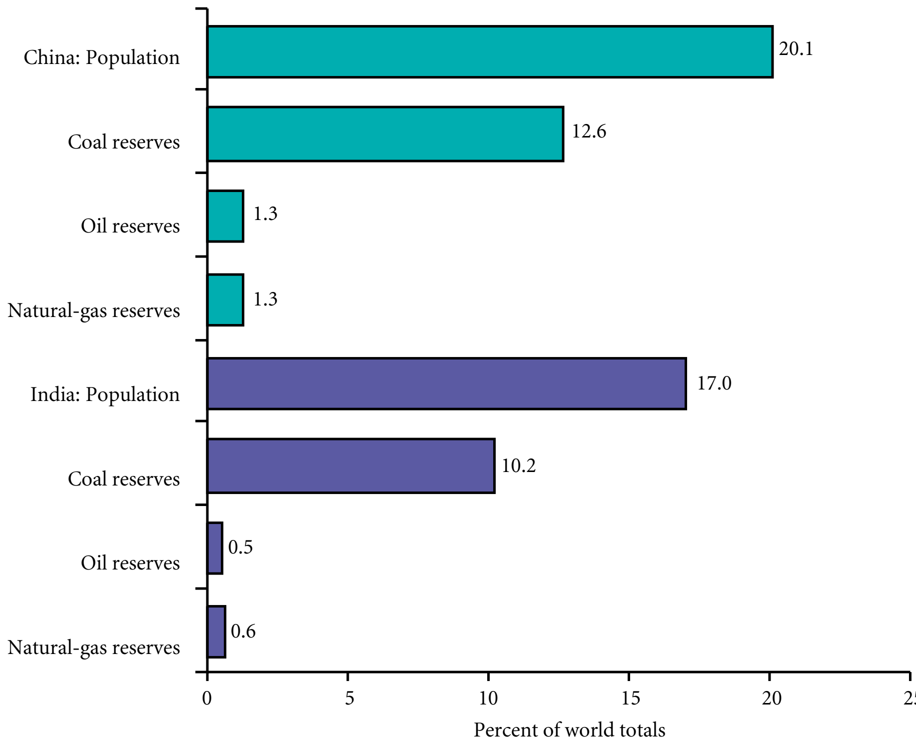
These concerns are not limited to policymakers in China and India. As Asia's two largest countries compete in world markets for energy supplies, they create insecurity for other countries in the Asia-Pacific region and around the world.

In the 10 years from 1995 to 2005, China and India together accounted for one-third of all the growth in global demand for oil. And this pattern is projected to continue. Over the next 20 years, demand for oil, natural gas, and other energy sources will rise much more quickly in China and India than in the world as a whole. Thus energy consumption in these two countries—and the policies they pursue to supply their energy needs—will be of tremendous importance for the rest of the world.

While there are many differences between China's and India's energy situation, a number of similar characteristics stand out. Demand for oil is skyrocketing in both countries, driven primarily by the growing number of motor vehicles. Demand for natural gas is also increasing rapidly, albeit from a much smaller base. With their limited reserves of oil and natural gas, domestic production lags further and further behind consumption.

Coal is the principal energy source in both countries, and both have large coal reserves. But concerns about the environment are prompting efforts to improve coal-burning technologies and to switch to other, cleaner, fuels. Energy-security policies in China and India also include a strong emphasis on hydropower and nuclear power to produce electricity. And lastly, to reduce dependence on Middle-Eastern suppliers, state-owned companies in both

Figure 5.1. Share of China and India in global population and global reserves of coal, oil, and natural gas, 2005 (percent)



Sources: PRB (2005); BP (2006).

countries are aggressively looking for new sources of oil and natural gas. These efforts to diversify energy sources may slow down increasing dependence on imports from the Middle East, but they will not halt the overall trend.

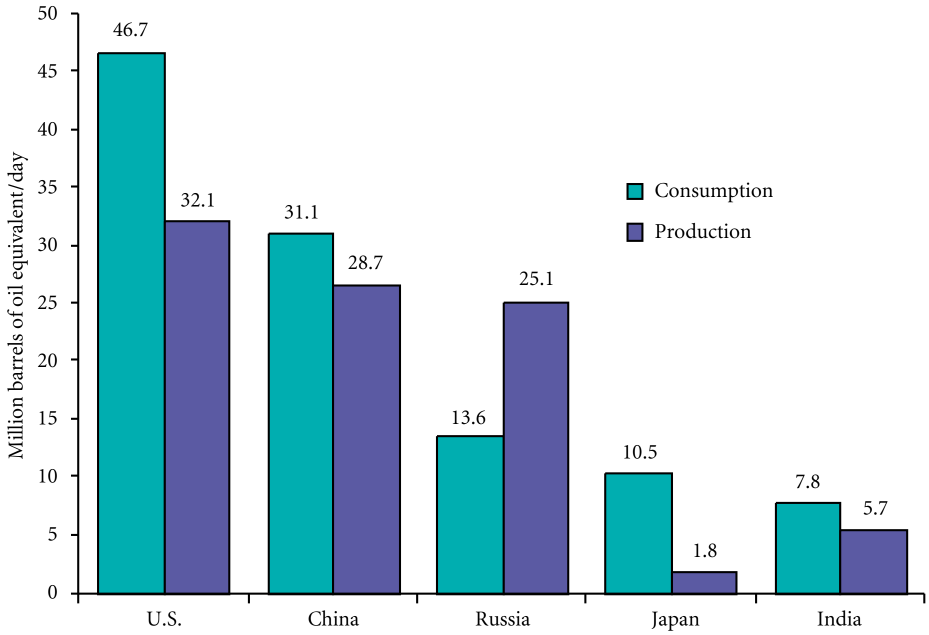
Demand for energy outpaces supply

China. China ranks second in the world in total primary commercial energy consumption, although a distant second after the United States (Figure 5.2). In 2005, consumers in China used primary commercial energy equivalent to 31.1 million barrels of oil per day (boe/d) (Appendix Table 5.1). They also used approximately 4.4 million boe/d of non-commercial energy from combustible biomass sources such as woodfuel, charcoal, and agricultural waste.

China uses so much energy because its population is so large. On a per-capita basis, China's primary commercial energy consumption is well below the world average. In 2005, per-capita primary commercial energy consumption for the world as a whole was 11.8 barrels of oil equivalent per annum (boe/a), compared with only 8.7 boe/a in China. Even with the addition of non-commercial energy, per-capita energy consumption in China was 9.9 boe/a, about 15 percent below the world average. This low level of per-capita energy consumption points to a strong potential for future growth.

Between 1980 and 2005, primary energy consumption increased at an average annual rate of 5.3 percent, linked to China's economic growth (Table 5.1 and

Figure 5.2. Primary commercial energy consumption and production by world's five largest users, 2005 (million barrels of oil equivalent per day: boe/d)



Sources: BP (2006); FACTS Global Energy (2006).

Figure 5.3). Consumption of all major sources of commercial energy increased steadily except during a five-year period between 1996 and 2000 when coal consumption went down. This exception to the overall trend stemmed from a decline in the use of coal in the residential and industrial sectors and a slowdown in the growth of coal use for power generation. Growth of coal consumption has since rebounded. Over the next 10 years, consumption of every type of commercial energy is expected to continue to grow steadily.

On the supply side, China has relatively abundant coal reserves (Table 5.2) but faces a major challenge in meeting the growing demand for oil and natural gas. In 2005, the Chinese produced 28.7 million boe/d of primary commercial energy—8 percent less than they used. The balance was made up of imports. Today, the Chinese are net importers of oil, and over the next five years they will also become net importers of natural gas. Overall, the gap between energy supply and demand is expected to widen, and increasing shortfalls will have to be supplied by imports.

India. At the global level, India ranks fifth in total primary commercial energy consumption after Russia and Japan (Figure 5.2). In 2005, the Indians used 7.8 million boe/d of primary commercial energy (Appendix Table 5.2) plus an estimated 4.2 million boe/d of non-commercial energy from combustible biomass. On a per-capita basis, primary commercial energy consumption in India is even lower than in China—at 2.6 boe/a in 2005. Adding non-commercial energy use results in an estimated 4.0 boe/a of total per-capita energy consumption. As in China, this low level of energy use points to enormous potential for growth.

Over the past 25 years, primary commercial energy consumption has been

Table 5.1. Annual growth rate of primary commercial energy consumption in China and India by source, 1980–2005 and 2005–2015 (percent)

Time period	Coal		Oil		Natural gas		Hydro-power		Nuclear power		Total	
	China	India	China	India	China	India	China	India	China	India	China	India
1980–2005	5.1	5.4	5.3	5.6	4.9	14.3	8.1	2.2	33.9[a]	7.4	5.3	5.5
2005–2015	4.2	2.2	5.0	3.5	11.1	9.0	7.8	5.1	17.7	12.7	5.0	3.7

Percent annual growth

Sources: OECD/IEA (2006); FACTS Global Energy (2006).
Note: Data for 2015 are projections.
[a] For 1993–2005.

Table 5.2. Proven reserves of fossil energy in China and India, beginning 2006

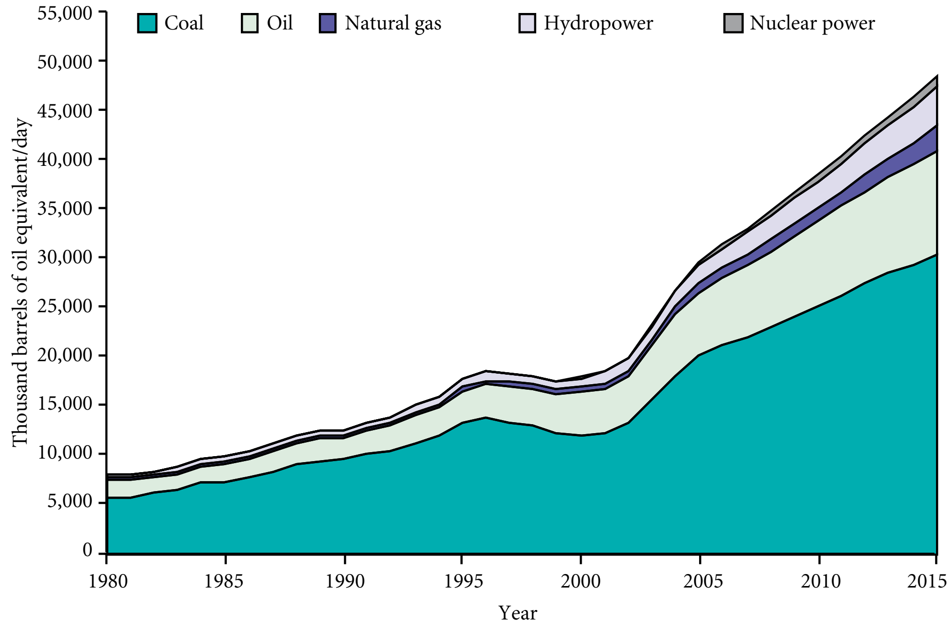
Country	Coal	Oil	Natural gas
China			
Reserves	114.5 billion tonnes	16.0 billion barrels	83.0 trillion cubic feet
Reserve-to-production ratio (R/P) (years)	52	12	47
Share of global reserves (percent)	12.6	1.3	1.3
India			
Reserves	92.4 billion tonnes	5.9 billion barrels	38.9 trillion cubic feet
Reserve-to-production ratio (R/P) (years)	217	21	36
Share of global reserves (percent)	10.2	0.5	0.6

Source: BP (2006).
Note: The reserve-to-production (R/P) ratio is the reserves remaining at the end of 2005 divided by production in 2005. The result is an estimated number of years that existing reserves can be expected to last if production continues at the same rate and no new reserves are discovered.

growing even more quickly in India than in China—at an average annual rate of 5.5 percent (Table 5.1 and Figure 5.4). As in China, projections indicate that energy consumption in India will continue to grow steadily over the next 10 years, albeit at a much slower rate.

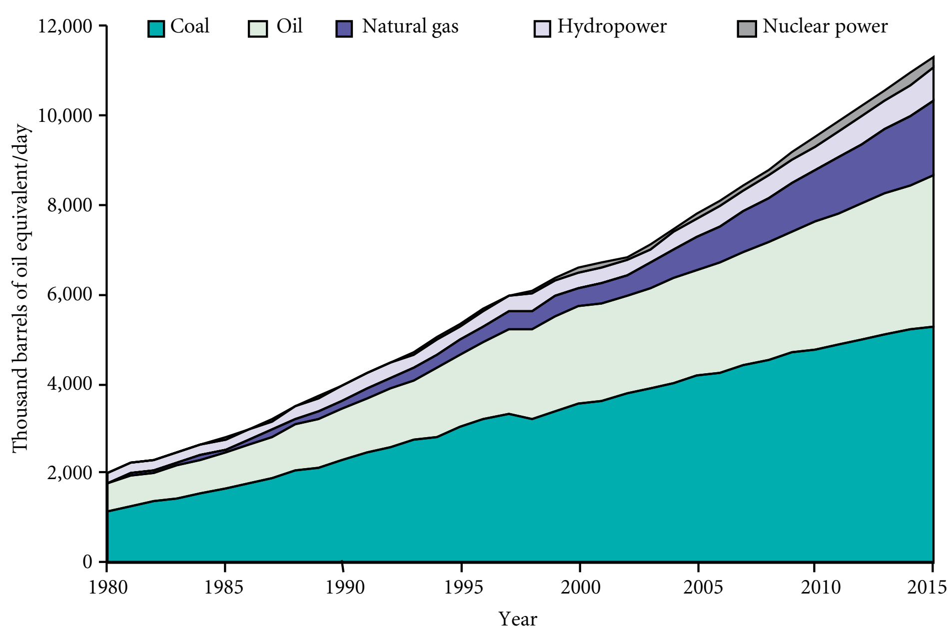
As in China, India has relatively abundant supplies of coal but very limited reserves of oil or natural gas. In 2005, the Indians produced 5.7 million boe/d of primary commercial energy—27 percent less than they used. Thus more than one-fourth of India's primary commercial energy was imported. India is already a net importer of coal, oil, and natural gas, and in the future, imports of all three commodities are expected to increase.

Figure 5.3. Primary commercial energy consumption from five leading sources, China, 1980–2015 (thousand barrels of oil equivalent per day: boe/d)



Source: FACTS Global Energy (2006).
Note: Consumption levels for years after 2005 are projections.

Figure 5.4. Primary commercial energy consumption from five leading sources, India, 1980–2015 (thousand barrels of oil equivalent per day: boe/d)



Source: FACTS Global Energy (2006).
Note: Consumption levels for years after 2005 are projections.

The dominant role of coal

Coal dominates commercial energy use in both China and India. The two countries have the third and fourth largest proven coal reserves in the world after the United States and Russia. China is the world's largest producer and consumer of coal, while India ranks third.

Coal is used primarily to generate electricity and also for industrial production. Because of their large domestic reserves, coal is relatively cheap in both countries, but coal combustion creates substantial health and environmental problems. For this reason, both China and India are trying to move away from coal toward cleaner fuels—most notably natural gas—but these efforts come at a higher cost and greater dependence on imports.

China. Coal is the most important source of primary commercial energy in China, with high consumption levels supported by large domestic supplies. China has estimated coal reserves of 114,500 million metric tonnes, 13 percent of the world total. At 2005 production levels, China's coal supplies should last an estimated 52 years, if no future domestic sources are discovered.

In 2005, three-fourths of all the coal used in China was for electricity generation. At the same time, coal fueled slightly more than three-fourths (78 percent) of all electricity generated in the country. Residential and commercial use has declined steeply—from 22 percent of all coal used in 1985 to 11 percent in 1995 and only 4 percent in 2005.

Apart from environmental concerns, coal production in China has been plagued with problems of mine safety, inefficiency, unlicensed mining operations, and over-mining. As a result, the government has closed many small, privately owned operations, reducing the total number of coal mines in the country from about 80,000 in the late 1990s to 28,000 today. In 2005, the eight largest state-owned coal mines accounted for 23 percent of total coal production.

In the past, China purchased technology and equipment from abroad but sought little foreign investment in the coal-mining sector. This situation is likely to change, however. As China seeks to build larger coal-production facilities and to meet higher environmental standards, foreign investors and providers of advanced technologies may find new opportunities to participate in China's coal sector. Countries likely to become involved include Australia, Germany, Japan, and the United States.

Between 1980 and 2005, coal consumption increased at an average rate of 5.1 percent a year (Table 5.1). This was somewhat slower than the average annual increase in total primary commercial energy consumption, at 5.3 percent. As a result, the share of coal in China's energy mix is going down—from 73 percent in 1980, to 70 percent in 2005, and to a projected 64 percent in 2015 (Table 5.3).

China has long been a net coal exporter, producing 2.1 billion tonnes in 2005 and consuming 2.0 billion tonnes. Yet an increasing amount of coal is also

Table 5.3. Proportion of total primary commercial energy consumption in China and India by source, 1980, 2005, and 2015 (percent)

	Percent of total primary commercial energy consumption											
	Coal		Oil		Natural gas		Hydro-power		Nuclear power		Total	
Year	China	India	China	India	China	India	China	India	China	India	China	India
1980	73.0	55.8	20.8	30.1	3.1	1.2	3.1	12.2	0.0	0.7	100.0	100.0
2005	69.7	54.6	20.8	29.7	2.8	9.1	5.9	5.6	0.8	1.0	100.0	100.0
2015	64.3	47.2	20.7	29.0	4.9	15.0	7.7	6.4	2.4	2.4	100.0	100.0

Sources: OECD/IEA (2006); FACTS Global Energy (2006).
Note: Data for 2015 are projections.

imported to meet booming demand in the southern part of the country. It is cost-effective to import coal because the primary consuming region is far from the main domestic centers of supply. In 2005, China exported 60 million tonnes of coal, primarily to Japan, the Republic of Korea (South Korea), Taiwan, and India (in order of importance), and imported 24 million tonnes, primarily from Australia, Indonesia, and Vietnam.

Over the next 10 years, China's coal production is expected to increase steadily, rising to 3.0 billion tonnes by 2015. Consumption is forecast to grow even faster, however. Over the next 5 to 10 years, China is likely to become a net coal importer.

India. Coal is the most important source of primary commercial energy consumption in India, although its share is not as high as in China. As in China, the importance of coal is diminishing—from 56 percent of total commercial energy use in 1980, to 55 percent in 2005, and to a projected 47 percent in 2015 (Table 5.3).

India has estimated domestic coal reserves of 92,445 million tonnes, 10 percent of the world total. At 2005 production levels, India's domestic coal supply will last more than 200 years.

In 2005, India produced more than 426 million tonnes of coal and imported nearly 38 million tonnes (BP 2006; FACTS Global Energy 2006). Although low in sulfur, Indian coal has a high ash content and low calorific value, making it unsuitable for metallurgy. As a result, India's steel industry imports coal for coking, mainly from Australia and New Zealand. India exports small quantities of coal to Bangladesh, Bhutan, and Nepal.

The importance of coal in India's energy mix is based on the country's large domestic reserves and the predominance of coal in the power sector. Today, almost three-fourths of India's electricity is generated from coal. Given that the demand for electricity is expected to grow at an average annual rate of 5–7 percent through 2015, the demand for coal will also rise significantly. Frequent power cuts around the country are an indication of growing demand that the current production system is struggling to meet.

Nearly 90 percent of the coal produced in India comes from the state-owned Coal India Limited (CIL) and its subsidiaries. There has been a move to bring greater dynamism and efficiency into this sector by relaxing government controls over pricing and distribution and allowing private-sector participation in coal mining. Foreign participation has also been initiated, subject to certain clearances. These changes are an attempt to make coal production more competitive and to tackle the emerging problem of demand outstripping supply.

The high ash content of Indian coal raises special environmental concerns, which have contributed to a trend toward stricter pollution standards. The government now requires coal to be washed to remove ash before it is shipped to new generating plants, to environmentally sensitive areas, or over distances of more than 1,000 kilometers (km). India currently has a capacity to wash 63.5 million tonnes of coal a year—less than one-sixth of total coal production.

The government is also promoting a switch to natural gas for power generation. Any new gas-fired power plants that are built will probably be sited far from coal deposits in locations where piped or liquefied natural gas (LNG) can compete with coal in terms of costs. Yet with prices of oil and natural gas rising steadily, it will be difficult to replace coal, which is much less expensive. Large hydropower projects, which could fill some of the demand for electricity, are meeting stiff resistance from local communities on environmental grounds. All of these factors point to the continued importance of coal in India's energy sector.

Oil—primary focus of security concerns

In both China and India, oil is at the heart of growing concerns about energy security. Compared with their huge populations, both countries have low domestic reserves. This was manageable in the past when China and India had little manufacturing capacity, low use of electricity, and small numbers of motor vehicles. The situation is changing dramatically, however, with economic growth. Over the next 10 to 15 years, oil consumption is expected to increase rapidly in both countries, driven primarily by the transportation sector. Both countries need to ensure a sufficient supply of transportation fuel for the growing number of motor vehicles, and they also need oil for power generation and as feedstock in the petrochemical and industrial sectors.

Despite some new oil discoveries in recent years—in Rajasthan in India and the Tarim Basin and offshore in China—domestic production has remained stagnant in both countries. In 2005, 44 percent of the oil consumed in China and 73 percent of oil consumed in India was imported. The trend is toward even larger oil imports and greater dependence on the primary source or supply, the Middle East.

China. Oil is the second-largest source of primary commercial energy in China, although a distant second after coal, accounting for 21 percent of consumption in 2005 (Table 5.3). Between 1980 and 2005, oil consumption increased at the same rate as total commercial energy use, averaging 5.3 percent a year (Table 5.1 and Figure 5.3).

At this rate of increase, China recently overtook Japan as the largest oil consumer in Asia. Projections indicate that total oil consumption (petroleum products plus direct use of crude oil) will reach 8.6 million barrels per day (b/d) in 2010 and 10.5 million b/d in 2015. These projections are very sensitive to alternative assumptions, however. Demand growth could be faster or slower depending on the growth of the economy, price changes, and other factors.

At the beginning of 2006, China had 16 billion barrels of proven oil reserves, or 1.3 percent of the world total (BP 2006). The Chinese government claims to have much larger oil resources, however, including proven plus probable and possible reserves. Based on 2005 production levels and the internationally accepted estimate of China's oil reserves, China's domestic oil supply is projected to last another 12 years unless significant new sources are discovered (Table 5.2).

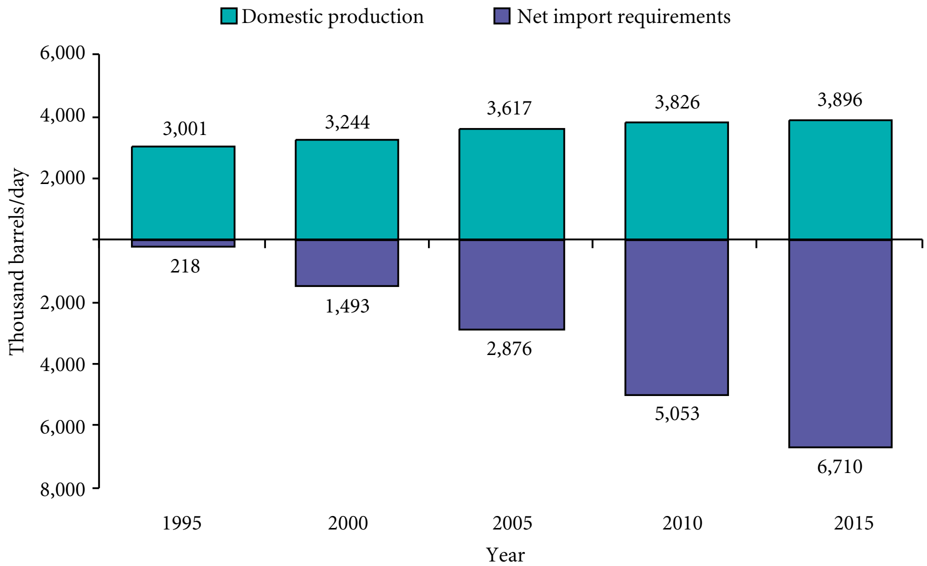
While consumption has grown dramatically since 1980, China's domestic production of crude oil has stagnated. In 1993, China shifted from a net oil exporter to a net importer, and imports (including both crude oil and petroleum products) have risen steadily ever since (Figure 5.5). In 2005, China produced 3.6 million b/d of oil but consumed 6.5 million b/d. During the year, China imported nearly 3.4 million b/d of crude oil and refined products and exported 500,000 b/d, resulting in net imports of 2.9 million b/d. Net oil imports are expected to continue rising for the foreseeable future in line with rising consumption.

Nearly one-half of Chinese oil imports come from the Middle East (Figure 5.6), and despite government efforts, this proportion is growing. Because of price volatility in global oil markets and rising oil imports from a region that is considered unstable, energy security has become a major concern for Chinese policymakers.

India. As in China, oil is the second most important source of primary commercial energy in India after coal. Oil accounted for 30 percent of total consumption in 1980 and 2005, projected to decline slightly to 29 percent in 2015 (Table 5.3). Between 1980 and 2005, oil consumption grew at an annual rate of 5.6 percent, slightly faster than in China (Table 5.1).

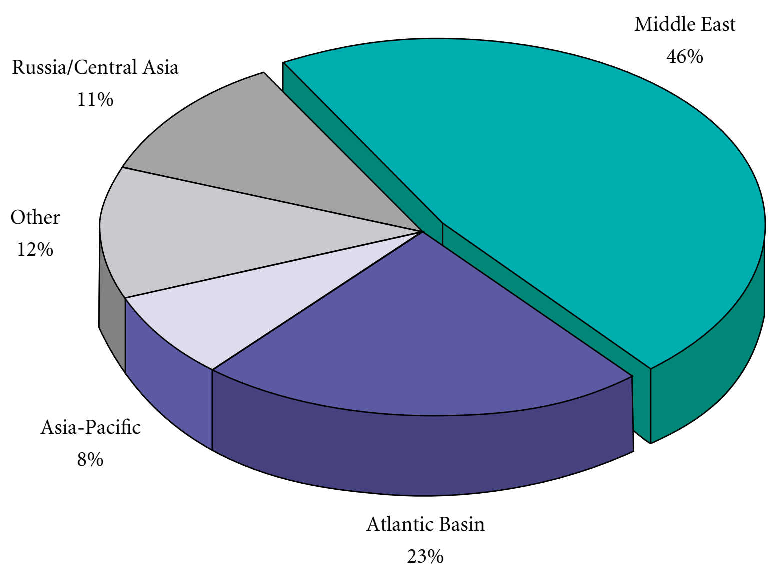
In recent years, consumption growth has slowed down, and this trend is likely to continue. Between 2005 and 2015, oil consumption is projected to increase at an annual rate of 3.5 percent. There are several reasons for this trend. India's economic growth is increasingly concentrated in sectors such as information technology that do not require intensive use of energy, and

Figure 5.5. Domestic oil production and net import requirements, China, 1995–2015 (thousand barrels per day: b/d)



Source: FACTS Global Energy (2006).
Note: Domestic production and import requirements for years after 2005 are projections.

Figure 5.6. Sources of China's crude-oil imports, 2005 (percent)



Source: China, General Administration of Customs (2006).
Note: Total crude-oil imports in 2005 were 2.5 million barrels per day (b/d).

consumption of natural gas is increasing, substituting to some extent for oil. Government efforts to reduce the use of oil in the public-transportation sector have also played a role in slowing consumption growth.

At the beginning of 2006, India had proven domestic oil reserves of about 5.9 billion barrels, less than 1 percent of the world total (Table 5.2). At 2005 production levels, India's domestic oil supply will last an estimated 21 years.

India produced 645,000 b/d of crude oil in 2005 and consumed 2.4 million b/d. The balance, two-thirds of India's oil consumption, was supplied by imports. With production likely to plateau or even decline in some of India's mature oil fields, the country will continue to be heavily dependent on imported oil, even if new domestic sources are discovered (Figure 5.7).

India is likely to require about 2 to 3 million b/d of imported crude oil over the next few years. Currently, India is far more dependent on the Middle East for oil than is China. In 2005, the Middle East accounted for more than two-thirds of India's crude oil imports (Figure 5.8). The Atlantic basin, comprising West Africa and Europe, came a distant second, providing less than one-fifth of imports.

Dependence on the Middle East is not likely to change. Atlantic-Basin crude oil contains less sulfur than oil from the Middle East, making it easier to refine to meet increasingly stringent environmental standards. Existing and new refineries in India are currently being upgraded, however, to improve the processing of Middle-Eastern grades of crude oil to reduce their sulfur content. The motivation is financial: Middle-Eastern oil sells at a discount because of its low quality, and freight costs are also low because the region is close to India.

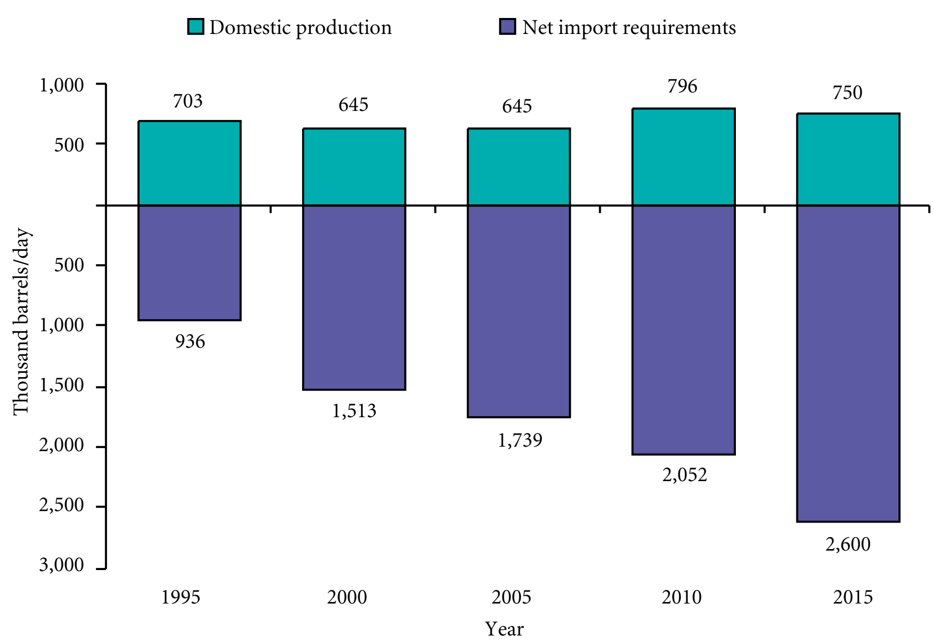
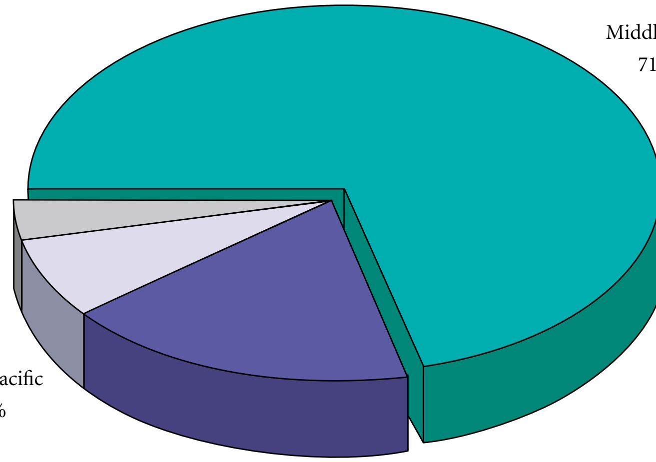


Figure 5.7. Domestic oil production and net import requirements, India, 1995–2015 (thousand barrels per day: b/d)

Source: FACTS Global Energy (2006).
Note: Domestic production and import requirements for years after 2005 are projections.

Figure 5.8. Sources of India's crude oil imports, 2005 (percent)



Source: FACTS Global Energy (2006).
Note: Total crude-oil imports in 2005 were 2.0 million barrels per day (b/d).

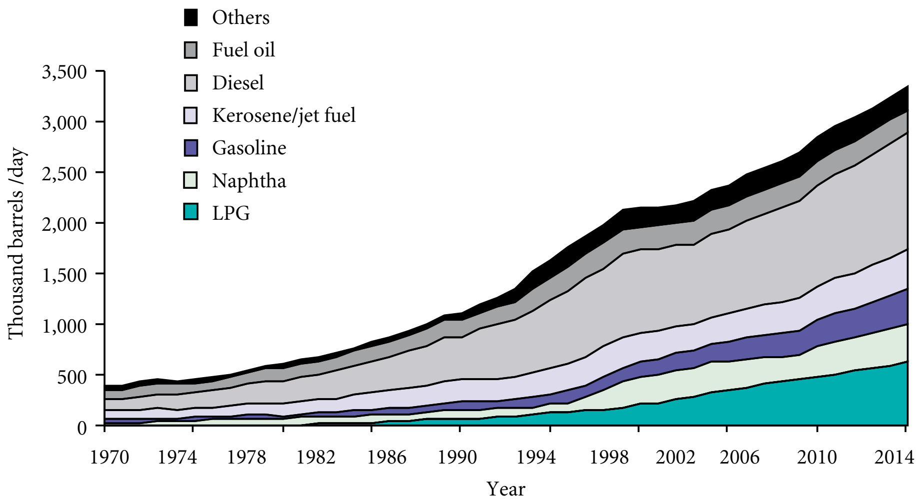
The mix of petroleum products in India's overall oil consumption is of particular interest because India is emerging as a major exporter of petroleum products, refined largely from imported crude oil. Consumption of liquefied petroleum gas (LPG, consisting of propane and butane) is growing, mainly used as household cooking fuel (Figure 5.9 and Appendix Table 5.3). Naphtha consumption is also growing in India's petrochemical industry, and gasoline consumption is growing due to rising numbers of privately owned vehicles. In recent years, demand for other petroleum products has been steady or declining.

India currently exports diesel, gasoline, naphtha, and fuel oil. Juxtaposing shifts in demand with projected changes in India's refining capacity indicates that India will continue to have a deficit of LPG, most of which is currently purchased from the Middle East (Figure 5.10). The more significant trend, however, is India's emergence as an exporter of all other petroleum products.

These surpluses have arisen as a consequence of over-projecting domestic demand. Many of India's oil refineries were built in the late 1990s and early 2000s to supply the domestic market. The recent slowdown in consumption growth has transformed India from a major importer of petroleum products to an exporter. India's surpluses have contributed to surpluses in the regional market and have depressed the profitability of refinery operations throughout Asia and the Pacific.

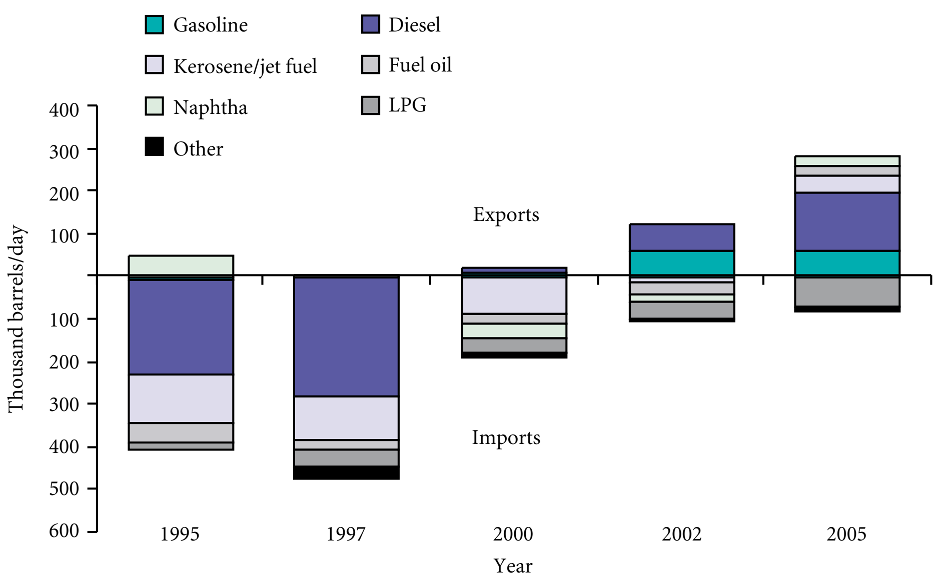
Despite this situation, refining capacity in India is slated to continue to expand. As a result, India will remain an important petroleum-product exporter through the end of this decade. To meet domestic demand plus excess refining capacity, India will be forced to import expanding supplies of crude oil.

Figure 5.9. Consumption of petroleum products in India, 1970–2014 (thousand barrels per day: b/d)



Source: FACTS Global Energy (2006).
Note: Consumption levels for years after 2005 are projections.

Figure 5.10. India's trade in petroleum products, 1995–2005 (thousand barrels per day: b/d)



Source: FACTS Global Energy (2006).
Note: Exports and imports are on net basis.

Natural gas

Natural gas accounts for a very small percentage of primary commercial energy consumption in China and India, but this percentage is growing fast. Both countries have strong incentives to increase natural-gas use: to reduce dependence on imported oil and to help control urban air pollution. Up to now, both countries have relied primarily on domestic sources of natural gas, but this situation will change as consumption goes up. Over the long term, both countries will be forced to increase natural-gas imports significantly.

China. In 1980 and 2005, natural gas accounted for only 3 per cent of primary commercial energy consumption in China, projected to rise to 5 percent by 2015 (Table 5.3). The Chinese government's plan is to double the share of natural gas in the nation's overall primary commercial energy consumption by 2015, requiring increases in both domestic production and imports.

After a late start, China's natural-gas industry has developed rapidly since the late 1990s. Today, China's gas consumption is supplied almost entirely from domestic sources. Spurred by the high demand for energy in general and for electric power in particular, domestic pipelines are under construction. One terminal to process imported LNG is now in operation, and a second is under construction.

The first terminal, recently completed in Guangdong Province, received its first shipload of LNG in May 2006. This terminal has a capacity to receive and process up to 3.7 million tonnes per annum (t/a). The second terminal, in Fujian Province, has a targeted completion date of 2008 and a projected capacity of 2.6 million t/a. Thus together, total LNG imports through these two terminals could reach 6.3 million t/a. In addition to these two projects, the China National Offshore Oil Corporation (CNOOC), the China National Petroleum Corporation (CNPC or PetroChina), and the China Petrochemical Corporation (Sinopec) have proposed several LNG terminals for development over the next 10 years.

Although it is unlikely that all of these projects will materialize, Chinese facilities to receive and process imported LNG will undoubtedly expand over the next decade, reaching a projected capacity of 18.5 million t/a in 2015. There appears to be a gap between planned LNG receiving capacity and projected LNG imports, however, suggesting that China's new LNG terminals may be substantially underutilized. Regional and global LNG markets are becoming tighter, and it is unlikely that China will be able to purchase enough LNG to meet its ambitious goals for increased consumption. LNG imports are conservatively projected to reach 14 million t/a by 2015, equivalent to 1.8 billion standard cubic feet per day (scf/d). This would only utilize about three-fourths of planned capacity.

On the domestic side, China has 83 trillion standard cubic feet (scf) of proven natural-gas reserves, 1.3 percent of the world total. At the 2005 production level of 4.9 billion scf/d, China's current proven reserves will last another 47 years.

TRANSPORTATION FUEL AND URBAN AIR POLLUTION

Most of the increase in oil consumption in China and India has been, and will continue to be, driven by the demand for fuel in the transportation sector. This has important implications for the mix of petroleum products required from the nations' refineries and also for national efforts to curb urban air pollution.

Transportation fuel has become the largest source of air pollution in many Asian countries. Although still lagging behind Australia, Japan, New Zealand, South Korea, Taiwan, and some Southeast-Asian nations, China and India are both making efforts to promote cleaner use of gasoline and diesel in the transportation sector.

China has been moving toward higher emission standards since the late 1990s. This effort began with the phasing out of leaded gasoline. In 2004, the government introduced Euro II emission norms, which limit the sulfur content in gasoline and diesel used in automobiles to 500 parts per million (ppm). In July 2005, Beijing introduced Euro III standards, which limit the sulfur content to 150 ppm in gasoline and 350 ppm in automobile diesel. Shanghai and Guangzhou are also scheduled to adopt these more stringent standards. By 2007, China plans to adopt Euro III standards throughout the country. Euro IV standards (a maximum of 50 ppm of sulfur in both gasoline and diesel for automobiles) will be adopted in Beijing in time for the 2008 Olympics, to be followed by Shanghai and Guangzhou in 2010.

Commuters battle traffic and haze during rush hour in Chiang Mai, Thailand. To help control urban air pollution, India and South Korea have started using compressed natural gas (CNG) in some public-transportation vehicles. © REUTERS/Sukree Sukplang/Landov

India first embarked on an aggressive program to tighten quality specifications for petroleum products in the early 2000s and then shifted to a more moderate approach. In April 2005, Euro III emission norms came into force in Agra, Ahmedabad, Bangalore, Chennai, Delhi, Hyderabad, Kanpur, Kolkata, Mumbai, Pune, and Surat. Euro II norms are currently being adopted throughout the country. The plan is to extend Euro III norms to the rest of India by 2010 and to raise standards to the Euro IV level in the nation's 11 largest cities. In addition, the Indian Supreme Court decreed that public-transportation vehicles in Delhi be converted to use compressed natural gas (CNG).

Other specifications for refined oil products are also being tightened in India. Higher product standards mean higher production costs, however. To meet higher standards, Indian refiners need to invest heavily in desulfurizing and treatment facilities. Because local refiners have been unable to complete these upgrades in time to meet higher specifications, retailers have had to resort to costly imports of diesel and gasoline as a stopgap measure.

Domestic production is projected to rise significantly above 2005 levels, however—to 9.2 billion scf/d in 2015. Assuming this level of domestic production growth plus rising imports, China can be expected to have 12 billion scf/d of natural gas to supply domestic consumption by 2015. If China's domestic gas production grows more slowly than these projections assume, and if some of the planned import projects do not materialize, then natural gas available for consumption could be as much as one-third lower.

China currently has no international pipelines for importing natural gas, but the government is exploring opportunities for constructing pipelines, possibly from Sakhalin or western Siberia by 2015 and from Kazakhstan and Turkmenistan by 2020. Increased use of natural gas will also require a network of domestic pipelines. China has accelerated the construction of new gas pipelines since the mid-1990s, building more pipelines in the past decade than during the previous four decades combined. Urban distribution networks have also expanded. The largest of the newly built natural-gas pipelines is the 4,000-km West-East pipeline. Others are mainly in western, northwestern, and northern China, plus a few offshore.

Cost is a major concern. Natural gas is expensive, even if it is produced domestically, because China's gas fields are far from centers of consumption, requiring huge investments in long-distance pipelines. And international prices are going up. Consumers may be unwilling to pay high prices for energy derived from natural gas in spite of government efforts to expand this sector.

Currently, industrial use accounts for nearly one-half of China's natural-gas consumption because natural gas is an important component in fertilizer production. In 2005, residential/commercial use accounted for 21 percent of natural-gas consumption, while electric power generation and heating accounted for 8 percent. Over the next 10 years and beyond, growth in natural-gas consumption will be led by the power and residential sectors. Consumption in the chemical sector and other industrial sectors will also increase, but at a slower pace. The transport sector will also consume more natural gas in the form of CNG.

India. Natural gas plays a central role in India's energy policy, promoted as an alternative fuel for environmental reasons and to reduce dependence on oil imports. Although consumption levels are still modest, natural gas is the fastest-growing source of energy in India, growing from 1 percent of primary commercial energy consumption in 1980, to 9 percent in 2005, and to a projected 15 percent in 2015 (Table 5.3).

In 2005, India imported 4.5 million tonnes of LNG, accounting for about one-fifth of total natural-gas consumption. A policy to increase the use of natural gas will inevitably translate into greater demand for LNG imports. This is because anticipated consumption cannot be met out of domestic production, and international pipelines are still at the discussion stage.

Petronet LNG Limited received India's first shipment of imported LNG in

2004, making India the fourth LNG importer in Asia. These first imports were purchased under a 20-year contract with RasGas of Qatar and were received at the newly constructed Dahej terminal in Gujarat. Shell's Hazira terminal, also in Gujarat, began receiving imported LNG in April 2005. Recently, the Gas Authority of India Limited (GAIL) and the Indian Oil Corporation (IOC) signed a 25-year contract to import LNG from the South Pars field in Iran. IOC and GAIL are planning to partner with Iran's Petropars to develop a gas-liquefaction plant in Iran, which will produce LNG for export to India and other countries.

The Foreign Investment Promotion Board (FIPB) approved 12 prospective LNG import-terminal projects in the mid- to late-1990s, but not all of them are expected to be constructed. The Dahej terminal has a capacity to receive 7.5 million t/a, and the Hazira terminal has a capacity of 5.0 million t/a. A third terminal, at Dabhol, is nearly complete, but construction was suspended when Enron went bankrupt. Recently, the government has set up a Special Purpose Vehicle (SPV) to revive the Dabhol facility, and it is expected to be at least partly operational by the end of 2007. Additional LNG import terminals have been proposed for several locations. At the same time, the domestic pipeline infrastructure is being developed to carry locally produced natural gas and re-gasified LNG to various parts of the country.

India, Bangladesh, and Myanmar are discussing construction of an international gas pipeline, and there are also discussions about building a pipeline from Iran to India through Pakistan. Despite these talks, it is unlikely that India will receive natural gas through international pipelines until at least 2015.

Up until now, most imported LNG has been directed to India's industrial sector, primarily substituting for more-expensive naphtha in refineries and other industries. The government is promoting the use of natural gas for power generation, however, and as an alternative transport fuel in the form of CNG. In the future, the power sector will certainly be the most important user. In addition, natural gas will be used increasingly as a component of fertilizer.

Hydropower and nuclear energy

Given the rising cost of oil and natural gas and concerns about dependence on imports, both the Chinese and Indian governments are placing increasing emphasis on domestic sources of energy. At the same time, both countries are trying to slow down the expansion of coal consumption because of negative health and environmental impacts. All of these concerns point to a renewed emphasis on hydropower and nuclear energy.

China. China's energy planners have traditionally placed heavy emphasis on hydropower. Hydropower accounted for 3 percent of China's total primary commercial energy consumption in 1980, rose to 6 percent in 2005, and is projected to rise to 8 percent by 2015 (Table 5.3). About two dozen large hydropower projects have been constructed over the past few decades with a minimum installed capacity of 1,000 megawatts (MW) each. At the end of 2005, China had approximately 117,000 MW of installed hydroelectric capacity, including part (9,800 MW) of the gigantic Three-Gorges project. Upon its full completion in 2009, the Three-Gorges hydropower plant will be the world's largest, with a capacity of 18,200 MW. Current government plans call for continued construction of hydropower facilities, with emphasis on both very large and small projects.

China did not begin building nuclear power plants until 1982, despite early development of indigenous nuclear technology. Nuclear energy accounted for less than 1 per cent of primary commercial energy consumption in 2005. In light of current electricity shortages, however, nuclear energy is poised to grow more quickly in the future. It is projected to provide nearly 3 percent of China's total primary commercial energy by 2015.

The first Chinese nuclear power plant, at Qinshan in Zhejiang Province, started commercial production in 1993. The next two plants went into production in 1994, at Daya Bay in Guangdong Province. Four more plants began producing power in 2002, followed by one in 2003 and one in 2004. These nine plants brought China's total installed nuclear-power capacity to 6,856 MW at the end of 2004. Following the completion of a tenth plant, at Tianwan, China had a total installed nuclear-power capacity of 8,956 MW at the end of 2005. Current plans include nuclear power plants in three additional locations that will bring total capacity up to nearly 15,000 MW.

According to several observers, the Chinese government plans to increase nuclear power dramatically in the longer term—to 40,000 MW by 2020. This would comprise 4 percent of China's total capacity to generate electricity. To reach this target, at least 2,000 MW of new nuclear power needs to be added every year between 2005 and 2020.

China has enough domestic uranium resources to meet short- and medium-term fuel requirements for the expansion of nuclear power. Construction and operation of nuclear facilities are expensive, however, and the government has to provide full support to sustain this source of energy. In addition, over the long term, further exploration will be needed to increase domestic uranium supplies.

India. Current hydroelectric capacity in India is 32,335 MW, or 26 percent of total installed power capacity. While hydroelectric power is an important source of energy, its share has declined over time (Table 5.3). Between 1980 and 2005, consumption of hydropower grew at an average annual rate of only 2.2 percent, compared with the 5.5 percent annual growth for primary commercial energy consumption as a whole (Table 5.1).

The growing demand for electricity in India has led to a renewed interest in hydropower. The government plans to add another 9,815 MW of hydropower

RUSH TO INVEST IN ENERGY PRODUCTION OVERSEAS

Both China and India view overseas investment as a critical component of efforts to secure future energy supplies. China began investing in overseas oil and natural-gas projects in the early 1990s and intensified investment activities toward the end of the decade. In recent years, the Chinese state-run oil companies have been engaged in an all-out effort to expand overseas. Faced with escalating demand for petroleum products combined with stagnating domestic production, the Indian government has also encouraged local oil companies to invest in exploration and production projects in other countries.

Judging from their investment record to date, Chinese and Indian companies have a long way to go to develop a successful overseas-investment strategy. In many instances, the Chinese and Indians have bid on projects that the major international oil companies deemed too risky or unprofitable. In the late 1990s, for example, the Chinese company CNPC paid substantially higher prices for oil exploration and pipeline projects in Venezuela and Kazakhstan than the major international oil companies were willing to pay.

Chinese and Indian oil companies have also bid up prices by competing against each other and against companies from other countries such as Brazil and Malaysia. In October 2005, for example, CNPC won the bid to take over PetroKazakhstan for US$4.18 billion, a high price that resulted from competitive bidding. In some instances, Chinese and Indian companies have been able to cooperate, as demonstrated by joint investments in Syria and Sudan, but such cooperative ventures are highly challenging for policymakers in both countries.

In their search for new sources of energy, China and India face a market that is dominated by the developed countries and the major international oil companies. For this reason, they are forced to focus on countries whose regimes, for various reasons, are at odds with the United States and other Western nations. Such countries include Bolivia, Cuba, Iran, Myanmar, Sudan, Syria, and Venezuela. Energy enterprises in these countries may be vulnerable to disruption as a result of internal dissension or external intervention.

Do China's and India's overseas oil and natural-gas investments actually promote their energy security? On the surface, it is always helpful to have a variety of supply options. But the cost has been high in economic terms. Both China and India have good supplies of labor and access to well-developed engineering and drilling technologies. Companies in both countries need to make better use of these advantages and seek out investment opportunities that are actually profitable.

by 2010, to be developed largely by national and state government bodies but including joint ventures with the private sector. Constraints on future projects include an unfavorable tariff structure, negative environmental effects, shortage of long-term finance, problems of land acquisition, and difficulties in resettling affected populations. To address these problems, the government has set out a National Policy for Hydropower Development that includes provision of financing, gives priority to upgrading and renovation of existing projects, and provides government support for land acquisition, resettlement, and catchment-area development.

India has been using nuclear power to generate electricity since 1969, but on a small scale. Although use of nuclear power grew by 7.4 percent a year between 1980 and 2005, the share of nuclear power in India's primary commercial energy consumption is still low, at around 1 percent in 2005.

India is not a signatory to the Nuclear Non-Proliferation Treaty and until recently was prohibited from international trade in nuclear technology and materials. To address global concerns about nuclear proliferation, the Indian government has introduced legislation on Weapons of Mass Destruction and their Delivery Systems. The goal is to gain international acceptance so that India can collaborate with other countries on nuclear technology.

In July 2005, the United States and India signed an agreement lifting the U.S. ban on the sale of non-military nuclear technology and materials to India and providing assistance to develop India's nuclear-power capability. U.S. President George Bush expressed his intention to strengthen this relationship during a visit to India in March 2006, and the 2005 agreement was ratified by the U.S. Senate nine months later.

Partly because India was banned from international trade in nuclear materials and technologies, Indian scientists have achieved self-reliance in the entire nuclear fuel cycle. India is also working to achieve self-sufficiency in uranium exploration and mining, heavy-water production, design and construction of reactors, and management of nuclear waste.

In 2005, nuclear power accounted for 3 percent of India's electricity generation. With completion of the Tarapur-4 reactor in September 2005, India now has 15 nuclear-power reactors in operation with a combined capacity of 3,150 MW (Fesharaki and Murata 2006). Thirteen of India's reactors use domestic uranium, but the other two require enriched uranium, which is not available from local sources. This enriched uranium was imported from Russia before the Nuclear Non-Proliferation Treaty went into effect. Although India's domestic uranium reserves are limited, it has abundant reserves of thorium, and new technologies are currently being developed to use these large thorium reserves as nuclear fuel.

Eight additional nuclear reactors are under construction. Expected to be operational by 2008, they will more than double the current installed capacity to 6,730 MW. All are owned and operated by the state-owned Nuclear Power

Corporation of India. As these construction projects indicate, nuclear power is expected to play a growing role in India's energy sector. Plans are to have 20,000 MW of nuclear capacity by 2020, half of the capacity that is planned in China.

Despite fears over the safety of nuclear reactors and the disposal of radioactive waste, the expansion of nuclear energy is based on other—overriding—concerns. These include India's growing dependence on oil imports, rising oil prices, escalating demand for electricity, increasing pollution from the use of fossil fuels, and public resistance to large hydroelectricity projects.

Policies to enhance security of energy supplies

In looking toward the future, policymakers in China and India face a similar challenge—to assure adequate energy supplies that will support rapid economic growth and meet the rising aspirations of their huge populations. To achieve these goals, policymakers in both countries are trying to diversify sources of energy and reduce dependence on imports. Both countries have also taken measures to increase strategic energy stocks and improve the efficiency of energy markets.

China. To enhance energy security, the Chinese government emphasizes reliance on domestic energy sources and stresses that coal will continue to be China's most important fuel. Policymakers call for diversifying sources of energy imports, improving links with international energy markets, establishing a national petroleum storage system, developing alternative fuels to replace oil, and adopting more energy-efficient technologies.

A full-fledged energy-security policy is still evolving in China (Gao 2003; Wu 2002), but discussions include the following objectives:

- Enhance domestic oil and natural-gas exploration and production
- Reduce dependence on oil by promoting the use of natural gas and nuclear power and developing liquefaction technologies to produce gasoline and diesel from coal
- Set up government-controlled strategic oil and natural-gas stocks and raise mandatory stockpile requirements for large oil companies
- Help develop a regional energy community and a regional energy-security system
- Establish an oil futures market
- Diversify sources of oil and natural gas by increasing the share of imports from Russia and Central Asia
- Expand overseas investment by state oil companies, particularly in the Middle East, the Asia-Pacific region, Russia, and Central Asia
- Increase investment in oil and natural-gas infrastructure and open additional routes for imports

One serious concern is that China has just started a national strategic petroleum-storage system. The current stockpile system is fragmented, and facilities are in the hands of individual refineries, pipeline companies, and sales agencies. There is a National Office of Strategic Petroleum Stockpiling, however, housed in the Energy Administration under the National Development and Reform Commission (NDRC). The current target, to be achieved by 2008, is to have 100 million barrels of oil in storage, about 25 days of the net oil imports or 14 days of the oil consumption projected for that year. China is setting up a special government agency and consortium to manage the necessary storage facilities, and the state oil companies may also be involved. The longer-term target is to have 189 million barrels in storage by 2010, about 37 days of projected net imports or 22 days of projected consumption.

China began investing in overseas oil and natural-gas assets in the early 1990s and stepped up these efforts in the latter part of the decade. Since 2000, the Chinese state oil companies have greatly expanded overseas investments, an initiative strongly favored and encouraged by the Chinese government. The state oil companies have been able to take advantage of the central government's concern about energy security to achieve their business objective of expanding operations around the world. This international thrust has become a cornerstone of the overall investment strategy of every state oil company in China.

The most active of China's state oil companies in this area is CNPC and its publicly listed subsidiary PetroChina. CNOOC and Sinopec have also been active in overseas investment. In addition to these three, Sinochem Corporation and two state-owned companies—China International Trust and Investment Company (CITIC) and China Zhenhua Oil Co. Ltd.—have begun investing in oil operations overseas.

CNPC/PetroChina was the first Chinese state oil company to invest in the overseas oil sector, initiating an investment in Peru in 1993. The company currently has production-sharing contracts, joint-venture projects, lease contracts, and other projects in Algeria, Azerbaijan, Canada, Ecuador, Indonesia, Iran, Kazakhstan, Mauritania, Myanmar, Nigeria, Oman, Peru, Sudan, Syria, Turkmenistan, and Venezuela.

CNOOC's overseas investments are mainly in Algeria, Australia, Canada, Indonesia, Kazakhstan, Kenya, Morocco, Myanmar, and Nigeria. Sinopec has projects in Algeria, Azerbaijan, Brazil, Canada, Ecuador, Iran, Kazakhstan, Kuwait, Saudi Arabia, and Yemen.

India. Given concerns about India's dependence on imported oil from the Middle East, policymakers are pursuing several options to improve the country's energy security. To increase domestic supplies, the government is trying to attract foreign companies to participate in oil exploration and production. So far, this approach has met with limited success, and, in fact, most new licenses have been awarded to local firms.

The government is also encouraging Indian oil companies to participate in oil and natural-gas exploration and production projects overseas. The argument is that control of overseas oil fields can help ensure the security of India's oil supply. This policy holds great appeal for Indian oil companies that find participating in overseas projects a promising way to invest their cash holdings and consolidate their position in the industry. The main company involved is Oil and Natural Gas Corporation (ONGC) Videsh Limited, or OVL, which is the overseas arm of ONGC India. OVL is currently involved in exploration and production projects in Côte d'Ivoire, Egypt, Iran, Iraq, Myanmar, Nigeria, Sudan, Syria, and Vietnam.

The third aspect of India's energy-security strategy is to develop strategic oil stocks. This approach has been considered for some time, but concrete action has been inhibited by the cost involved. Currently, the plan is to maintain a stock of crude oil equivalent to about 15 days of consumption (approximately 38 million barrels), increasing eventually to an equivalent of 60 days of consumption. The oil stocks would include mandatory inventory requirements for refiners plus government-held stocks financed by a tax on refiners and importers.

Continuing energy challenges

China and India face a long list of energy challenges. These include ensuring adequate supplies to meet future energy demand and reducing the adverse health and environmental effects of energy use. How China and India manage these issues will affect the welfare of more than one-third of the world's population.

Both countries have to deal with a rapidly expanding demand for energy, and both have large rural areas where the supply system for commercial energy is weak. To the extent possible, both need to move away from coal to cleaner—but more expensive—fuels. Both need to deregulate domestic energy markets and put foreign energy investment on a more rational footing to help ensure the security of future energy supplies. And both countries need to moderate the growing consumption of all types of energy without risking a political backlash or sacrificing economic growth.

Commercial energy consumption is nearly four times as large in China as in India, and environmental problems are much more severe. China is much more heavily dependent than India on coal, and China faces severe problems related to coal use, including urban air pollution, acid rain, transportation bottlenecks, and production safety. China also has a long way to go to improve energy efficiency and increase energy conservation.

India is already more heavily dependent than China on energy imports, and in the future, India will face increasing shortfalls in domestic supplies of oil and natural gas. India's population is also growing much faster than China's. Today, nearly one-third of India's one billion people live in poverty, presenting the government with the daunting challenge of providing affordable energy to the rural and urban poor. The government has approached this problem by controlling energy prices and subsidizing the price of LPG and kerosene, the main commercial energy sources used by the poor. At the same time, however, India's energy markets need to move toward privatization and deregulation in order to attract foreign investment. These two priorities—deregulating markets and providing energy to the poor—tend to be conflicting, which poses a challenge for policymakers.

In addition to domestic concerns, energy policies in China and India have an important impact on the Asia-Pacific region and the world. The rapid increase in oil consumption and oil imports in China and India contributes to higher oil prices worldwide. Consumption trends in China and India also affect the world market for natural gas. And finally, energy use in China and India can have adverse environmental effects on neighboring countries, the Asia-Pacific region, and the world as a whole.

CHAPTER SIX

Policy Priorities

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Energy security—defined as access to reliable, affordable, and environmentally sustainable energy supplies—is a top priority throughout Asia and the Pacific. Escalating demand for energy in the face of supply constraints, growing concern about the environment, economic and political sensitivity to energy prices, and over-dependence on oil from the Middle East—all of these developments have greatly increased the stakes for policymakers in recent years. Today, the Asia-Pacific region faces an energy-security dilemma of unprecedented dimensions (see Energy Insecurity Index). What can the region's policymakers do to increase energy security in their countries?

Activists protest a hike in gasoline and diesel prices in Jammu, India. Economic and political sensitivity to energy prices contribute to a policy dilemma in Asia and the Pacific.
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Full energy security is an elusive goal. Very few countries in the world have sufficient energy supplies to meet all conceivable demand. In Asia and the Pacific, only tiny Brunei Darussalam is truly independent in terms of energy. Every other country in the region is dependent on international energy markets. This dependence is particularly troubling because many of the factors that might create an international energy crisis—such as a political upheaval in the Middle East—cannot be controlled or even significantly influenced by countries in the region.

Given this situation, business as usual is not an option. The global energy markets have changed in a spectacular fashion, and these changes are irreversible. The prices of oil and natural gas have moved to a new plateau, and it is now recognized that the global supply of oil will reach its maximum limit within a decade, given both policy and resource constraints.

The world's number-one consumer, the United States, continues to consume more and more of the world's oil and natural-gas resources. At the same time, emerging economies, such as China and India, are in a race to secure access to the energy they need for economic development. And the impact of alternative energy technologies will be limited, at least for the next decade or two. Policymakers must pursue innovative, or even sometimes radical, programs and policies to survive in the new global energy environment.

Asia-Pacific countries, and the region as a whole, must address the problem of energy security by taking forceful policy actions that in the short-to-medium term will hedge against supply interruptions and price volatility and in the medium-to-long term will improve the relationship between supply and demand, ultimately through exploiting and developing new energy sources. And this must be done in the context of improving environmental sustainability. We propose a series of steps in each of these three areas.

Policies that protect against price volatility and supply breakdowns

Price fluctuations have been, and will continue to be, an important characteristic of the world oil market. Sudden increases in oil prices, known as price shocks, can have a severe effect on national economies, especially in countries that are heavily dependent on imported oil. As their import needs rise, countries in Asia and the Pacific will be increasingly vulnerable to oil price volatility. The fact that oil is bought and sold in U.S. dollars exacerbates the risk when a country's currency is devalued vis-à-vis the dollar. Policies designed to avoid or lessen the effects of market disruptions include building strategic stockpiles, developing a regional futures market for oil and natural gas, improving regional cooperation, and mitigating the domestic impacts of short-term market instability.

1. Build up strategic oil stocks. One of the most obvious approaches to help ensure energy supplies in the Asia-Pacific region is to develop or augment strategic fuel stocks. As members of the Organization for Economic Cooperation and Development's International Energy Agency (OECD/IEA), Japan, the Republic of Korea (South Korea), Australia, and New Zealand maintain mandatory stocks of oil equivalent to at least 90 days of net oil imports. Japan currently holds national strategic oil stocks equivalent to about 92 days of consumption, managed by the state-owned Japan Oil, Gas, and Metals National Corporation (JOGMEC). In addition, the Japanese government requires private companies to hold stocks of crude oil and petroleum products equivalent to about 80 days of consumption.

Although not an OECD/IEA member, Taiwan is also relatively well prepared for potential supply disruptions. The Taiwanese government requires both the state-owned CPC Taiwan and the privately owned Formosa Petrochemical Corporation (FPC) to maintain stocks equivalent to at least 60 days of anticipated sales.

As a regional refining center and oil-trading hub, Singapore has large commercial stocks on hand at any given time. In addition, the Singapore government requires its three state-owned power companies to maintain oil stocks equivalent to 90 days of consumption.

Thailand requires domestic suppliers to keep an inventory equivalent to at least 5 percent of annual petroleum-product sales, equivalent to 18 days of consumption. In addition, the Thai government is planning to start maintaining strategic oil stocks.

Other countries are much more exposed to supply shortages. China just started a government stockpiling program. Until recently, India maintained commercial stocks equal to only 15 days of consumption, with no government stocks.

In 2004, China began constructing storage facilities for oil stocks at four sites. One has been completed, and the other three are scheduled for completion by

2007 or 2008. Under Phase I of the plan, China will hold 100 million barrels of strategic oil stocks by 2008, which is equivalent to more than 30 days of net oil imports at the 2005 level. India is also planning to establish strategic stocks. Initially, the Indian government's plan calls for holding at least 35 million barrels of strategic oil stocks before 2010, equivalent to about 20 days of India's net oil imports in 2005.

In planning the development of strategic oil stocks, policymakers need to make decisions in several important areas. For one thing, these facilities are expensive to build, and many countries simply cannot afford them on their own. The high costs involved suggest the value of international assistance or cooperation among neighboring countries.

Once financing has been obtained, policymakers must choose an appropriate site and ensure the safety of oil stocks, which may remain unused for many years. Other policy decisions include the timing of oil purchases to build up stocks, the organizational structure of the stockpiling system, the optimum size of stocks, and decision criteria and mechanisms for releasing stocks onto the market. Policymakers throughout the Asia-Pacific region need to tackle these issues and move toward the OECD/IEA standard of maintaining stocks equivalent to 90 days of net oil imports.

2. Establish a regional futures market for oil and natural gas. The United States and Europe have had futures markets for oil and natural gas for decades, but efforts to launch an international futures market in the Asia-Pacific region have failed up until now. A local futures market in Japan—the Tokyo Commodity Exchange (TOCOM)—has been modestly successful, but only for Japanese consumers and suppliers.

The two existing international markets in oil futures—the International Petroleum Exchange (IPE) in London and the New York Mercantile Exchange (NYMEX)—play a critical role in the global oil trade. In the United States and Europe, the volume of oil futures ("paper contracts") amounts to about 300 million barrels per day (b/d). This volume of trade, which includes contracts for oil to be delivered up to five years in the future, is substantially larger than the trade in physical crude oil, which ranges from about 40 to 45 million b/d. The constant turnover of futures contracts leads to better price clarity for both buyers and sellers. In addition, the use of financial tools, such as options and derivatives, has brought a great deal of transparency to the market and has allowed both buyers and sellers to hedge their risks.

Buyers and sellers in Asia and the Pacific cannot easily use the oil futures markets in the United States or Europe because they are, in effect, trading a different commodity—Dubai crude—rather than West Texas Intermediate (WTI) or Brent crude. Although it is possible to use any futures market to mitigate risk, traders in Asia and the Pacific have been reluctant to use the American or European futures markets to hedge their positions because direct linkages are difficult to establish. This disconnect between global oil markets at times allows sellers to charge higher prices to customers in the Asia-Pacific region.

Without an oil futures market, companies and governments in the Asia-Pacific region have been more dependent than their counterparts in other parts of the world on physical (as opposed to paper) trade and informal mechanisms such as over-the-counter swaps. The physical trade in Dubai crude is very small, at 120,000 b/d, which limits price transparency, while the over-the-counter swap market lacks the security features provided by a futures exchange.

A promising new development, the Dubai Mercantile Exchange (DME), opened in 2006. With 50-percent ownership by NYMEX, the DME is the first energy futures exchange in the Middle East. In addition, the Dubai Metals and Commodities Centre (DMCC) began trading fuel-oil futures toward the end of 2006. Starting with a regional futures market for Dubai/Oman crude and fuel oil, these exchanges may eventually provide a market for other energy commodities.

It is not yet certain whether these two new initiatives will succeed, but they merit strong support from consumers in the Asia-Pacific region. In addition to improving market transparency and reducing risk, a futures market in Dubai crude will allow traders to buy and sell differentials between the three benchmark crudes, providing a natural and permanent linkage between markets and integrating the Asia-Pacific region into the global system. Governments in the region need to encourage their state and private companies to use these new exchanges.

3. Strengthen regional cooperation. Cooperation among countries/economies in the region can play an important role in countering the potential for unproductive competition over scarce energy resources. Many proposals have been made in recent years to enhance regional cooperation, often involving joint investments outside the region or joint development of infrastructure such as pipelines, ports, and processing facilities.

Members of the Association of Southeast Asian Nations (ASEAN) signed the ASEAN Petroleum Security Agreement (APSA) in 1986, which calls for oil-producing members to increase their exports to member countries that face oil shortages. ASEAN members include four oil producers and exporters—Brunei, Indonesia, Malaysia, and Vietnam—and one major petroleum-product exporter—Singapore. The five other members are oil importers—Cambodia, Lao People's Democratic Republic (Laos), Myanmar, the Philippines, and Thailand. The 1986 agreement also calls on oil-importing countries to increase their imports from any exporting members that face a situation of oversupply.

In fact, the measures laid out under APSA have never been invoked. It will be even more difficult to invoke the agreement in the future than it has been in the past because, with production flat and domestic consumption rising, the oil-producing countries in ASEAN have less and less crude oil available for export.

A more practical alternative would be to coordinate the maintenance of

Traders buy and sell oil futures at the New York Mercantile Exchange (NYMEX). Without a regional futures market for oil, companies and governments in Asia and the Pacific face higher prices and greater risks than their counterparts in Europe or the United States. © Daniel Acker/ Bloomberg News/Landov

A futures contract represents a commitment by a buyer and a seller to the future exchange of a commodity—such as oil or natural gas—for cash. Each contract specifies the type and grade of commodity to be exchanged, the amount, the price, and the time and place at which it will be delivered.

Futures contracts may be bought and sold many times before the specified delivery date of the actual commodity. And the value of a futures contract goes up and down—above or below the price at which the trade was initiated—depending on market expectations. If the market is functioning well, short-term futures prices and spot prices (for immediate delivery) tend to converge, as they do on the New York and London exchanges.

Two important functions of a futures market are to assure that contracts are standardized and to provide "price discovery," making prices known to buyers and sellers at any time. In providing price transparency, a futures market improves energy security by helping buyers and sellers detect market signals instantaneously. Speculative signals will have short-term impacts, but futures markets are able to perform well in the longer term.

In a futures market, both the buyers and sellers of a commodity—as well as speculators, who have no intention of taking physical delivery—can buy and sell futures contracts to "hedge," or transfer risk against adverse price fluctuations. By trading in futures, participants in the market will gain or lose smaller amounts of money than if they were simply buying commodities outright. They can also buy or sell at any time, taking advantage of favorable price fluctuations, and transaction costs are relatively low.

The exchange itself acts as a clearinghouse, functioning as a counterparty in every trade. When a futures contract changes hands, it is the clearinghouse that collects and disburses funds, protecting traders from the risk that a buyer or seller will default.

emergency stockpiles among countries in the region. The Asia-Pacific Economic Cooperation (APEC) group met at the East-West Center in August 2005 to discuss options for joint oil stockpiling and related cooperation. Members of APEC are Australia, Brunei, Canada, Chile, China, Hong Kong Special Administrative Region (SAR), Indonesia, Japan, South Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, the Philippines, Russia, Singapore, Taiwan, Thailand, the United States, and Vietnam.

The expansion and regional coordination of oil stocks is an important policy priority given the ever-increasing volume of oil imported into the region. National stocks could be held within a country's borders or offshore in jointly owned storage facilities. In either case, the initial financial requirements for constructing storage facilities and building up stocks could be substantial. The benefits of a coordinated effort may justify establishing a mechanism for more-affluent countries in the region to provide some initial financial assistance to their less-affluent neighbors.

APEC's Energy Working Group has considered joint projects to enhance energy security, but up until now action has been limited to conducting studies, and discussions have been on a project-by-project basis rather than aiming toward a comprehensive cooperative agreement. China, Japan, and South Korea have also discussed possible cooperative activities, and these three Northeast-Asian countries have held discussions with members of ASEAN. One potential area of cooperation is through collective bargaining to obtain lower prices and better terms on crude-oil imports from the Middle East. This concept has been discussed widely in Northeast Asia Petroleum Forums and meetings between ASEAN members and the three Northeast-Asian countries (ASEAN+3), but no collective-bargaining arrangement has yet been formulated because of concerns about a negative response from oil-exporting nations.

Although there are clear benefits to regional cooperation in the energy sector, there are also challenges. In recent years, there has been a gradual change in attitude, with countries in the region seeking closer ties not with each other, but with oil-producing nations in the Middle East and elsewhere. The rise of China as a growing oil importer has caused uneasiness among other oil importers in the region, particularly Japan.

Regional cooperation is also hampered by market restrictions. With countries in the region pursuing varying degrees of market deregulation, differences in domestic pricing policies and quality specifications for refined petroleum products have created a level of market segmentation that inhibits bilateral and multilateral trade. Despite the obvious benefits, there has not yet been any effort to coordinate product standards throughout the region.

Domestic politics and international tensions between countries pose additional barriers. Tensions between India and Pakistan, for example, have blocked development of a natural-gas pipeline from the Middle East through Pakistan to India. Similarly, internal politics in Bangladesh have made it difficult for India and Bangladesh to take advantage of cost-effective and mutually beneficial trade in natural gas.

Two steps are recommended for immediate action to increase regional cooperation in the energy sector: (1) develop joint oil stocks with financial assistance from Western nations; and (2) harmonize quality standards for petroleum products to facilitate interregional trade.

4. Mitigate the domestic impacts of short-term market instability. It is not easy for any government to come up with policies that deal effectively with disruptions in energy markets. If a short-term disruption rises to the level of a supply emergency, a government may consider releasing strategic stocks or calling for international assistance.

If the disruption takes the form of a price spike, the best approach is generally to leave price determination to the market and to concentrate on ensuring that market mechanisms are fully functional and that physical supplies are not disrupted. In some cases, policymakers may consider a managed price linkage, in which domestic prices are managed administratively but changes in international prices are reflected, at least partially, in the domestic market. Alternatively, a government may choose to provide direct subsidies to domestic energy suppliers or consumers, rather than imposing price or production controls administratively. Any administrative measure taken by a government to reduce the impact of high international prices should be temporary and should be replaced as soon as possible by long-term policies that allow market forces to determine the price of energy.

Policies that improve the relationship between supply and demand

Recognizing the importance of energy for economic growth, most Asia-Pacific governments place a high priority on ensuring adequate energy supplies. Oil and utility companies in Japan, South Korea, China, and India are scouring the world looking for new sources of oil and natural gas. Exploration for new energy sources and investment in production, refining, and transportation facilities may increase available supplies, at least in the short term. Other efforts—such as competition for long-term contracts with existing suppliers—may help individual companies or countries secure supplies but have little impact on supply and demand in the region as a whole. Some actions even serve to bid up prices without necessarily having much impact on supply.

Our second set of recommendations, therefore, is directed toward the development of clear and effective policies to increase energy supplies and to improve energy efficiency in order to slow down the growth of demand. Policies are needed in six areas.

1. Initiate joint ventures with energy producers. Over the years, a number of governments and private companies in Asia and the Pacific have invested in oil exploration and production enterprises outside the region. China, India, and Malaysia have made considerable effort to get a foothold in exploration projects in the Middle East. India's overseas push is led by the Oil and Natural Gas Corporation (ONGC). In China, the China National Petroleum Corporation (CNPC) is leading the effort, but other state oil companies are also involved.

Conversely, governments and companies from oil-producing regions have invested in refining and marketing enterprises in Asia and the Pacific. The Saudi Arabian state oil company Aramco, for example, has substantial investments in Asia-Pacific refining operations. Such joint investments have created equity partnerships that foster reliable flows of oil, enhancing energy security for Asian and Pacific consumers and revenue security for producers.

Joint projects could be expanded to include construction or expansion of oil-storage facilities. Middle-Eastern companies possess substantial oil-storage facilities in Europe and the Caribbean but none in Asia or the Pacific, despite the high volume of oil exported to the region. Atlantic-Basin oil producers might find regional storage facilities particularly beneficial to save on transport costs through economies of scale. The Norwegian company Statoil, for example, shares storage space for crude oil in South Korea under a cooperative arrangement with the state-run Korea National Oil Corporation (KNOC).

As a priority, joint ventures are recommended in four areas: (1) exploration and production projects; (2) refineries and retail operations in the Asia-Pacific region in cooperation with key oil producers; (3) shared storage facilities; and (4) joint infrastructure such as pipelines, ports, and terminals.

2. Reduce transportation bottlenecks. More than 90 percent of the crude oil imported into the Asia-Pacific region is shipped by sea tanker passing through the Malacca Strait (Figure 6.1). As this sea-lane—which is only 30 miles wide at its narrowest point—becomes more crowded, increased risks of accidents, piracy, or terrorist attack raise the possibility of a supply disruption. Indeed, the Malacca Strait is the Achilles heel of oil supply to East Asia and the Pacific. If the Strait had to be closed for any reason, ships would be diverted to a much longer route, dramatically increasing transport costs.

Because the Asia-Pacific region is so fragmented geographically and because oil resources are distributed so unevenly across the region, the potential for transporting oil by pipeline is extremely limited. At present, there are no pipelines bringing oil into the region. The only current alternative to oil shipped by sea tanker is a limited supply transported by railway from Russia and Kazakhstan to China. The one international oil pipeline currently under construction—from Kazakhstan to western China—will, at its maximum capacity, supply less than 10 percent of China's projected oil imports. Plans to supply oil by pipeline from Russia to Northeast Asia have been delayed by high costs and geopolitical barriers.

The dominance of Middle-Eastern oil and of sea-lane transportation is unlikely to change in the foreseeable future. Nevertheless, future development of

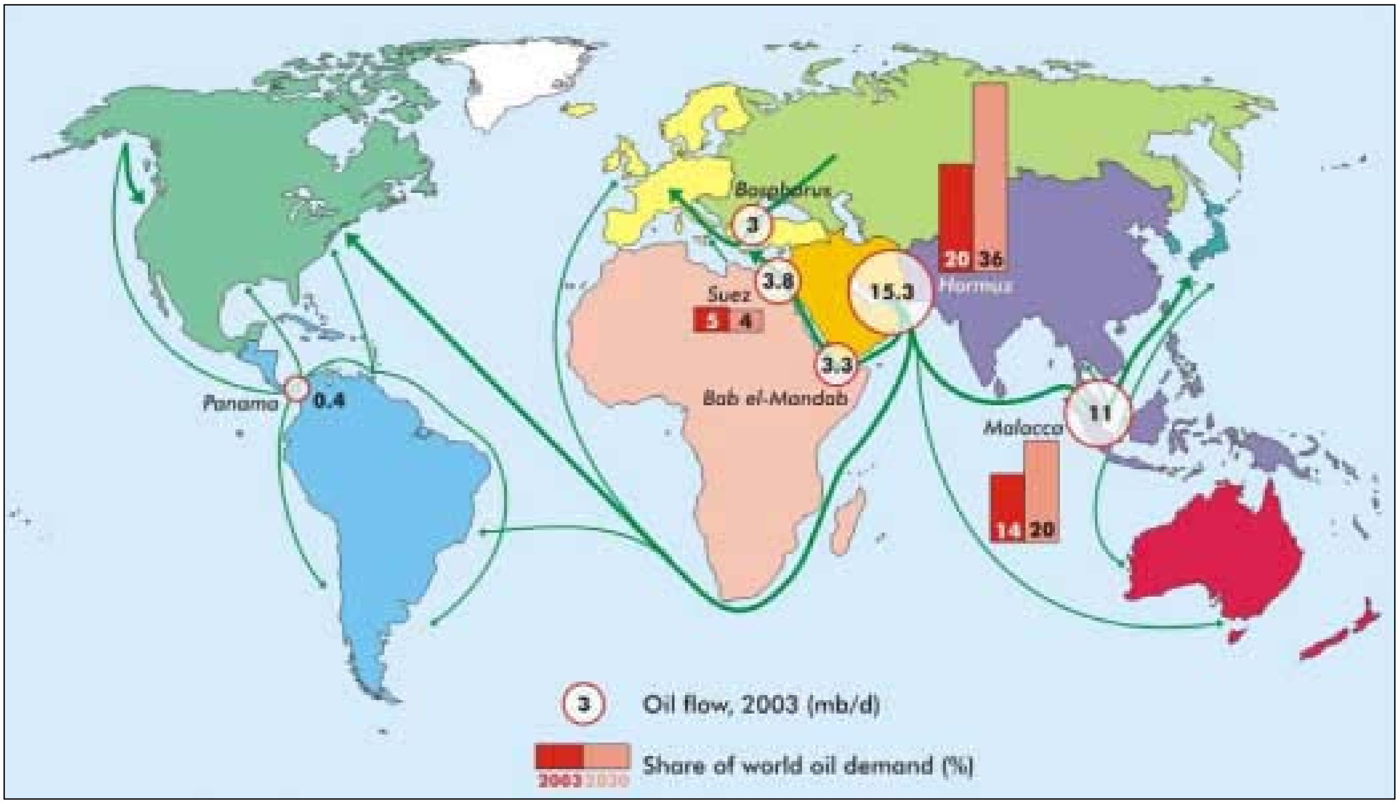


Figure 6.1. Maritime oil flows and major chokepoints, 2003 (million barrels per day: b/d), and share of world oil demand, 2003 and 2030 (percent)

Source: OECD/IEA (2004). [*World energy outlook* © OECD/IEA, 2004, Figure 3.25, p. 120].

oil pipelines will help China, Japan, and other Asia-Pacific nations diversify their sources of supply to some extent.

Pipelines and ports must be built based on economic considerations and not just political or security concerns. In our view, the most effective channel for exploring and assessing the possibilities would be through the creation of a multinational taskforce in the region to: (1) study alternative sea routes and improve security in the Malacca Strait through joint patrols; and (2) study potential pipeline routes, involving the private sector to assure that economic considerations receive priority.

3. Limit energy consumption through conservation measures. Energy conservation—through more efficient energy use—offers one of the most effective means to slow down the growth in energy demand and thus improve the balance between demand and supply. Current levels of energy efficiency vary widely throughout the region, but every country/economy in Asia and the Pacific could benefit from improved energy efficiency through new policies and technologies.

Indeed, energy conservation is a top priority in the region, particularly for China, India, and other rapidly developing economies. Today, the Chinese and

Indian economies are among the least energy efficient in the region—measured in terms of the amount of energy consumed per unit of Gross Domestic Product (GDP) (Figure 6.2).

The Chinese government introduced an energy-conservation law in 1998 and initiated a Special Program on Mid- to Long-Term Energy Conservation in November 2004. The program identified 10 areas in which energy-conservation projects would be implemented (Hai 2005). The target is to save 1.43 billion barrels of oil equivalent (boe) of energy over a five-year period from 2006 to 2010, equivalent to nearly 800,000 barrels of oil equivalent per day (boe/d). Recent conservation policies have included a modest increase in gasoline and diesel prices.

India has not yet introduced far-reaching energy-conservation measures, but Indian policymakers are coming to recognize the cost of inefficient energy use (EIA 2004). As in China, savings from improved energy efficiency could be substantial. Indonesia, Malaysia, Pakistan, Thailand, and Vietnam also have a long way to go toward improving energy efficiency.

By contrast, Japan is one of the world's most efficient energy users, thanks to strict energy-conservation policies. In addition, two Japanese companies, Honda and Toyota, are world leaders in the development of fuel-saving technologies for the transportation sector. Today, hybrid automobiles developed in Japan are contributing to better energy efficiency everywhere in the world—including the United States.

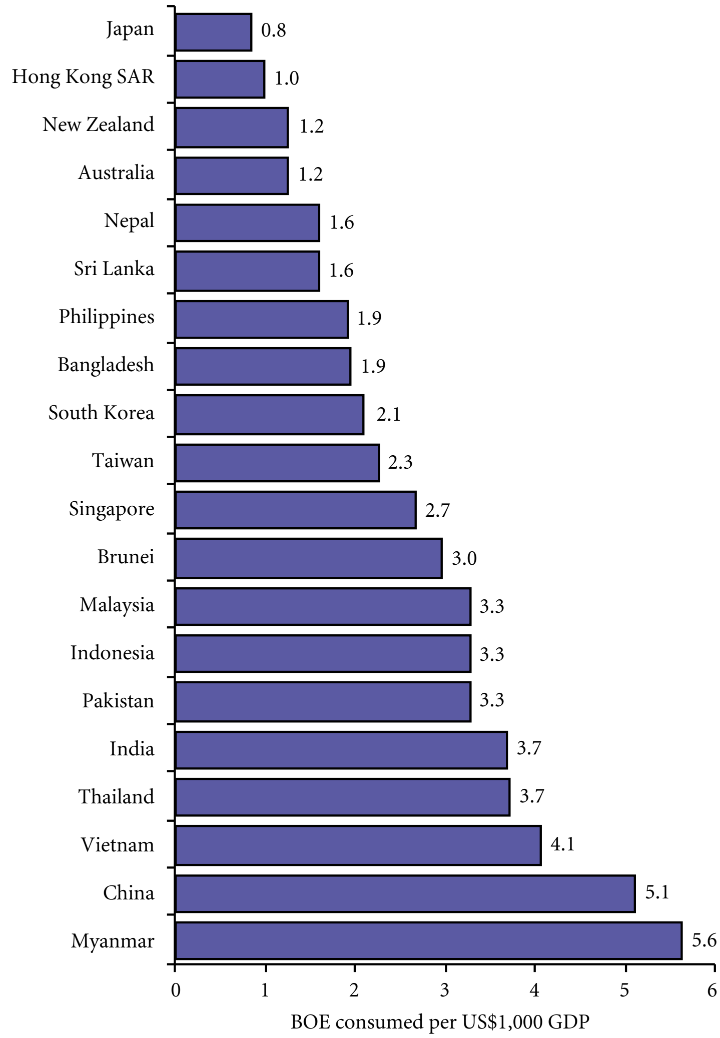
Australia and New Zealand also have comprehensive energy-conservation laws and government agencies responsible for implementation. Taiwan and South Korea are in an intermediate position, using energy somewhat more efficiently than the developing and newly industrialized economies in the region.

Asian and Pacific governments can take several steps to conserve energy by limiting consumption. Indeed, policies to manage energy demand should be given equal—or even higher—priority, compared with policies to ensure supplies and diversify sources of energy.

Excessive energy consumption can be curbed by reducing inappropriate government intervention, removing price distortions, and allowing market prices to reflect the true cost of energy. Policymakers need to continue the current trend toward market reform until energy prices are determined entirely by free-market forces. Tax benefits and incentives should be designed to encourage the use of energy-saving goods and services, such as hybrid automobiles, and to support increased use of renewable energy. In addition to these "carrots," policymakers will need to introduce "sticks" such as higher taxes on excessive energy consumption and higher mandatory standards for automobile fuel efficiency.

4. Improve the efficiency of energy markets. Many governments in Asia and the Pacific have intervened in energy markets to achieve specific policy goals. Some of these interventions have tended to reduce market efficiency, however. After decades of experience with different types of market interventions and regula-

Figure 6.2. Energy intensity of economic activity in selected Asia-Pacific countries/economies, 2005: Barrels of oil equivalent (boe) used per US$1,000 of Gross Domestic Product (GDP), based on exchange rates



Source: Compiled by authors.

tions, policymakers in the region are coming to realize that energy security—defined as an uninterrupted supply of energy at the lowest possible cost—can be achieved through the efficient operation of market forces. Since the mid-1990s, Asian and Pacific policymakers have witnessed the negative consequences of excessive market regulation and are adopting measures to liberalize energy markets.

In the past, many countries enacted policies to favor and protect domestic energy suppliers. This does not create a problem if local suppliers can provide energy at the lowest available cost. A problem arises, however, if domestic energy is more expensive than energy from sources available on the international market. In such a situation, a country may decide to subsidize the domestic source, which imposes a cost on taxpayers (who are also typically consumers), or to restrict or tax imports, which imposes higher prices on consumers directly.

In addition to supporting local energy suppliers, subsidies may be created to help a local industry (such as agriculture) or population group (such as the urban poor). The Indian government, for example, taxes gasoline and diesel in order to subsidize the price of kerosene and liquefied petroleum gas (LPG), which are widely used for cooking by the urban poor and middle classes.

In such situations, deregulating energy markets is likely to be disruptive to specific industries or segments of society. Largely for this reason, energy deregulation in countries around the region has moved in stops and starts. As a result, there is wide variation in national policies and regulations that affect the energy industry.

In the oil industry, differences in the regulatory environment have led to increasing refining capacity in some countries/economies and refinery closures in others. Some governments protect refiners by imposing high import tariffs on petroleum products compared with low tariffs on crude oil. In such a situation, refiners can charge high prices in the domestic market, thus artificially increasing their profit margins. Refiners operating in such an environment will tend to increase their capacity even though the domestic market has been adequately supplied. They will direct their surplus production toward the export market, depressing international market prices and lowering profit margins for refiners in other countries.

India, China, Japan, South Korea, and Taiwan all provide substantial tariff protection to their refiners. Tariff protection in India, in particular, has led to excess refining capacity, resulting in large exports of petroleum products. These exports have tended to depress the profitability of refinery operations in other countries of the region. Because the price of petroleum products is largely based on the international price of crude oil, consumers have not seen a drop in prices, however.

In recent years, domestic energy markets—the power sector in particular—have undergone some degree of deregulation in most countries of the region. Deregulation generally entails promoting competition by allowing more private-sector involvement, aligning domestic prices with international market prices, and phasing out government-owned monopolies. Among other advantages, deregulation promotes more efficient energy use and helps send clear market signals regarding the relative scarcity of competing fuels. Steps to improve market efficiency also include better exchange of information and coordination of product standards to facilitate trade (Fesharaki and Brown 2003).

Oil markets in Australia, New Zealand, Singapore, and Thailand have been fully deregulated for some time (Table 6.1). Markets in South Korea and the Philippines were fully deregulated relatively recently. In other countries/economies, some kind of effective protection remains, such as high import tariffs, restrictions on imports and/or exports, regulations that hinder new entrants into the market, or government interventions to set domestic prices.

Since joining the World Trade Organization (WTO) in 2001, the Chinese have begun opening their oil and other energy markets to foreign investors, while still attempting to assure the central role of their state oil companies. In

Table 6.1. Qualitative assessment of oil-sector deregulation: Selected Asia-Pacific countries/economies and the United States

Country/ economy	Tariff differential: Petroleum products vs. crude oil	Level of government involvement	Refining capacity management criteria	Entry of new players into the market	Years to complete deregulation
Australia	~0%	Low	Economic	Easy	1 (1988–1989)
China	6–9%	High	Government administered	Very difficult	2002–?
India	7–8%	High	Maximum utility	Very difficult	2001–?
Indonesia	5%	High	Government administered[a]	Very difficult	2001–?[b]
Japan	0–10%	Medium	Economic/ market share	Difficult	10 (1987–1997)
Malaysia	US$1/barrel tax break on domestic crude	Medium	Economic	Somewhat difficult	1985–?
Philippines	0%	Low in theory	Economic	Very easy	1 (1996–1997)
Republic of Korea	2%	Low	Economic/ market share	Possible but difficult	8 (1991–1999)
Taiwan	7–8%	Medium	Economic/ maximum utility	Difficult	7 (1995–2002)
Thailand	~0%	Low	Economic	Easy	3 (1991–1994)
United States	US$0.0000–0.0053/liter	Low	Purely economic	Easy	<1 (1980)

Source: Compiled by authors.
[a] Market reform in progress.
[b] Reform has been delayed.

Japan and Taiwan, oil imports are fully deregulated in principle, but restrictions are still in place that hinder participation by companies that are not refiners. Indonesia has recently passed legislation opening the domestic market, but the government faces a political dilemma: how to phase out price subsidies that are popular with consumers. Despite fairly large price increases in March 2005, the domestic market is still heavily subsidized. In Malaysia, the wholesale market for petroleum products is open and competitive, but the government regulates retail prices and limits the number of companies that can participate in the retail market. In 2006, the Malaysian government reduced subsidies and allowed retail prices to rise sharply.

Several countries have expressed an interest in moving toward a more open oil market—sometimes in response to outside pressure—but are still heavily regulated. In China and India, barriers to entry into the market are in place, domestic refiners are protected, and both governments intervene in pricing.

There is no consistent pattern in the relationship between a country's level of economic development and deregulation of oil, natural-gas, and other energy markets. For instance, among the high-income nations of the region, Australia is fully deregulated, but Japan is still in transition. In Thailand, a country at a much lower level of economic development, the oil industry has been fully deregulated for some time.

In fact, there is often a conflict of interest between state energy companies that enjoy a monopoly and economists who favor a quick move toward an open market. This is one area where policymakers in Asia and the Pacific need to move decisively and accept the political consequences of reform. Current half-hearted attempts need to expand to a full-fledged move toward free energy markets throughout the region.

5. Increase domestic energy supplies. Increasing domestic energy production is a top priority for virtually every country in the Asia-Pacific region. This includes countries that already produce substantial amounts of energy—Australia, Brunei, China, India, Indonesia, Malaysia, and Vietnam—as well as countries/economies that produce relatively little—Japan, the Philippines, South Korea, Taiwan, and Thailand.

High international prices since 2004 have provided particularly strong incentives for countries in the region to produce more oil and natural gas. As a result, oil production in Asia and the Pacific actually increased in 2004 and again in 2005, defying earlier predictions that production would decline. Given the region's limited reserves, however, oil production cannot continue increasing over the long term.

Even countries with few resources have managed to boost domestic energy production to some extent. Thailand, for example, only began producing oil in 1980, and up to 1990 Thai oil production was less than 60,000 b/d. Since then, production has more than doubled—to about 150,000 b/d in 2005. This level of production was achieved as a result of offshore exploration in the Gulf of Thailand, partly in cooperation with Malaysia. Similarly, the Philippines will start producing natural gas once the sizable offshore Malampaya field is developed. Even Japan and Taiwan maintain small levels of domestic oil production.

In several countries/economies of the region, there are good prospects for supplementing domestic energy supplies with nuclear power. Japan, South Korea, and Taiwan already produce nuclear energy to meet a significant proportion of their electricity needs. The Japanese government plans to increase the use of nuclear power to help reduce carbon-dioxide emissions as called for under the Kyoto Protocol. South Korea has plans to construct additional nuclear plants, and even in Taiwan—where the ruling Democratic Progressive Party has used opposition to nuclear power as a plank in its political platform—a new nuclear plant is being built, albeit with significant delays. China and, to a lesser extent, India also have ambitious programs to build additional nuclear-power capacity over the next 10 to 15 years.

To increase domestic energy production, it is recommended that governments in the region: (1) provide better terms and conditions for exploration and development of energy sources, including tax holidays, lower government royalties, a streamlined permitting process, and less red tape; and (2) increase financial assistance for the development of infrastructure.

6. Develop innovative energy sources. Although the potential for increasing oil and natural-gas production is limited, several innovative energy sources may contribute to future energy security in Asia and the Pacific. Many countries in the region have large biomass resources, including fuelwood and agricultural and animal wastes. Small-scale projects in several countries focus on improving the efficiency and environmental impact of biomass fuels used in households or to generate electricity on a small scale. Projects in China, for example, focus on power generation from biomass, marsh gas, and other sources (Li, Shi, and Ma 2006). Biomass projects are also ongoing in India and Vietnam. In New Zealand, tree plantations are being used for power generation.

China, India, Japan, and New Zealand are also interested in developing ethanol and other biofuels, produced from waste products or agricultural crops. These can partially substitute for oil in the transportation sector. Japan has recently introduced biofuels into the market, and use is expected to increase as supplies become available. The Chinese are currently building two large plants to produce ethanol. Current biofuel production in China is only a little more than 1,000 boe/d, but the goal is to increase production capacity to more than 20,000 boe/d.

Natural gas can be produced from methane that is present in most coal deposits, including those in several Asia-Pacific countries. Coal-bed methane accounts for 10 percent of total natural-gas production in the United States, but it has never been produced commercially in the Asia-Pacific region. Extracting coal-bed methane is expensive, and methane cannot be extracted from coal in every situation. The Chinese are currently exploring their coal-bed methane resources and developing production capacity. They should be producing coal-bed methane commercially by the end of this decade.

India has taken the lead in the development of wind power, supported by substantial government tax incentives. As of September 2005, India had the largest wind-power capacity of any developing country in the world, with installed capacity of 4,228 megawatts (MW). This represented 3 percent of India's total capacity to generate electricity. China had only 1,268 MW of installed capacity, but the Chinese are currently constructing a 1,000-MW wind-power facility in Inner Mongolia at a cost of US$1.2 billion. The Chinese government has ambitious plans to increase installed wind-power capacity to 5,000 MW by 2010. This would represent 0.2 percent of China's capacity for electricity generation. Australia, Japan, New Zealand, and South Korea also generate electricity from wind power, but the share in overall power generation is very small.

Australia, China, Japan, New Zealand, and South Korea all make limited use of solar energy. In addition, Australia, China, Indonesia, Japan, and New Zealand use geothermal energy, most frequently associated with volcanic or natural steam outlets.

Other innovative energy sources are being developed outside the region that may eventually be of benefit in Asia and the Pacific. These include non-conventional sources of oil—bitumen and oil sands—which can be mined and converted to heavy or synthetic oil. In Asia and the Pacific, Australia, India, and Indonesia have some potential heavy-oil resources (OECD/IEA 2005). China and Australia also possess oil shale that could potentially be mined and processed to produce oil. It is too soon to tell whether these resources will ever be commercially viable, however, given the high cost of extraction and processing.

In addition, there is speculation that the sea beds around Australia, Japan, and New Zealand contain rich resources of methane hydrates, formed when methane mixes with water under specific conditions. Commercial use is a prospect for the distant future, however (OECD/IEA 2005).

Finally, ongoing research to develop hydrogen fuel cells could be of great benefit to countries in Asia and the Pacific. In the long run, hydrogen and nuclear power offer the potential of a virtually infinite supply of energy. Hydrogen power offers a great deal more flexibility than nuclear power and has little or no effect on the environment, but considerable technological advance will be necessary before hydrogen power becomes commercially viable (Salameh 2004).

Policies that improve environmental sustainability

Early thinking about energy security was so heavily influenced by fears of supply interruption that environmental concerns received little attention. By the late 1980s, however, a rising dependence on fossil fuels and a new awareness of their role in air pollution and global warming made environmental protection and sustainable development key concepts in the debate on energy security.

Since the late 1990s, every major country in Asia and the Pacific has moved to some extent to tighten emission standards for fuels used in transportation, industry, and power generation. One example is the trend toward stricter limits on the sulfur content of high-speed and automotive diesel (Table 6.2). This policy trend is particularly important because the number of motor vehicles in most Asian countries is projected to more than double between 2005 and 2015.

As the process is ongoing, current regulations on emission standards vary

Table 6.2. Maximum allowable sulfur content in high-speed and automotive diesel, selected countries/economies in the Asia-Pacific region (parts per million: ppm)

Country/ economy	1998	2001	2002	2003	2004	2005
Australia	5,000	500–5,000	500–5,000	500	500	500
China[a]	2,000–5,000	500–2,000	500–2,000	500–2,000	500–2,000	350–500
India[b]	5,000	2,500	2,500	2,500	2,500	350–500
Indonesia[c]	5,000	5,000	5,000	5,000	5,000	5,000
Japan[d]	500	500	500	50	50	50
Malaysia	3,000	1,000	1,000	500	500	500
New Zealand	3,000	1,000	1,000	1,000	1,000	500
Pakistan	10,000	5,000	5,000	5,000	5,000	5,000
Philippines	5,000	2,000	2,000	2,000	500	500
Singapore	3,000	500	2,000	500	500	500
South Korea	500	500	500	430	430	430
Taiwan	500	500	350	350	350	50
Thailand	3,000	500	500	500	350	350

Source: Compiled by authors.
[a] For Beijing, 350 ppm required as of 1 July 2005.
[b] For entire country, 500 ppm required as of August 2005.
[c] Domestic refiners can make 1,000 ppm, although imports in general are at about 5,000 ppm.
[d] Industry met stricter standards in 2005 before government regulations came into effect.

widely among countries/economies in the region. Australia, Hong Kong, Japan, New Zealand, South Korea, and Taiwan have adopted environmental standards for petroleum products that are at or near levels required in the United States and Europe. China, India, and other South-Asian nations have the least-stringent emission standards in the region, while Brunei, Malaysia, the Philippines, Singapore, and Thailand in Southeast Asia are in an intermediate position.

Another approach to controlling urban air pollution is to require public-transport vehicles to switch from petroleum fuels to compressed natural gas (CNG). The government of India now requires buses and taxis in Delhi to use CNG, and in Seoul, South Korea, the government is promoting the use of CNG in buses.

In several developing countries of Asia and the Pacific, heavy reliance on coal has polluted the environment, caused widespread health problems, and created international tension as acid rain and industrial dust extend across national borders. These problems are particularly acute in China where power generation is increasing very rapidly, almost entirely based on coal. In 1987, China's total installed capacity to generate electricity was 100,000 MW. At the beginning of 2006, it was 500,000 MW. This growth in capacity represents a huge increase in the use of coal. In fact, in only five years—between 2000 and

2005—coal consumption in China nearly doubled. Even in the region's developed economies—Japan, South Korea, and Taiwan—coal plays an important role in power generation, producing high carbon-dioxide emissions.

Our third set of recommendations is directed toward improving the environmental sustainability of energy use. In addition to tighter emission controls, policies are needed in three areas to achieve meaningful levels of environmental protection that are politically acceptable and economically viable.

1. Expand the use of natural gas for power generation. Countries around the region are already moving to make greater use of natural gas for power generation. The main barrier is cost, especially now with global markets tight and prices at an all-time high. In addition to the cost of gas itself, switching to the use of natural gas requires massive initial investments in the construction of regasification facilities and pipelines. It also takes several years of development before such facilities become fully operational.

2. Accelerate the development and expansion of clean coal technologies. Given today's high cost of oil and natural gas, China and other countries in the region are not likely to reduce their dependence on coal in the foreseeable future. The Chinese and other coal users need to introduce improved technologies for coal combustion and post-combustion cleanup to reduce the environmental consequences of coal use. For example, power plants can reduce emissions of sulfur dioxide (SO_2)by adding flue gas desulfurizers. Effective technologies are available, although substantial capital investments are required to put them in place.

3. Expand the use of nuclear power. The case for the accelerated development of nuclear power as a source of energy is strengthened by environmental considerations. This is true even though the use of nuclear power entails its own environmental concerns, principally waste disposal and prevention of accidents. These concerns have stymied nuclear-power development in some countries, especially the United States. Yet the environmental problems related to nuclear power need to be balanced against the problems related to the use of fossil fuels.

A call for political will

In his January 2006 State of the Union message, U.S. President George Bush called for alternative technologies to help reduce America's addiction to oil, "which is often imported from unstable parts of the world." If this is a problem for the United States, it is an even greater problem for Asia and the Pacific. Both the United States and the Asia-Pacific region import more than 60 percent of their oil supply, but the Asia-Pacific region is much more dependent than the United States on oil from the turbulent Middle East.

Indeed, energy security has been an important issue for countries in the

Asia-Pacific region for many years. Efforts to enhance energy security have included policies to promote energy conservation, to diversify energy types and sources, and to maintain strategic stocks, as well as various forms of government intervention in energy markets. Over the years, governments in the region have learned from past mistakes that overregulation of energy markets does not necessarily ensure security, and many are moving to improve market transparency and the efficient operation of market forces.

Today, the challenge of energy security is greater than ever. The days of cheap and plentiful oil are over. World oil production is likely to reach a peak some time in the next 10 to 15 years and will not go up higher. Although production levels may stay at that peak for many years before they eventually start to fall, the world is probably entering an era of permanently high oil prices.

Given this prospect, government and business leaders will have to explore a variety of energy policies for the future. High oil prices, although painful for consumers, may provide a needed incentive.

With oil consumption still growing much faster than production, international cooperation could play an important role in the Asia-Pacific region in securing supplies from the Middle East and other oil-producing regions, bargaining for the best prices and contractual terms, and exploring and developing alternative sources of energy. In practice, however, heightened competition in international oil markets may work against cooperative efforts.

As a minimum, countries can enhance trade in oil and petroleum products by harmonizing quality standards and allowing the markets to determine price. Countries in the region are also on a path toward increased use of natural gas and, in some cases, hydropower and nuclear energy.

In addition to regional concerns, energy policies in Asia and the Pacific will have an important effect on the global energy balance. As the world's largest energy consumer, the United States bears an even greater global responsibility than countries in the region. Policymakers in the Asia-Pacific region and the United States must be willing to make bold and profound changes.

A number of specific measures have been described here to help boost energy security. These measures must be undertaken with full commitment: Half measures are not enough, and they may even make the situation worse.

Both innovative and long-standing approaches to ensure energy security—from projects that expand the use of alternative fuels to policies that improve market functioning and international cooperation—can only work if there is political will among countries in the region. As of today, the political will and commitment are only half-hearted. Higher oil prices and other changes in energy markets may act as catalysts to encourage more decisive action. The bottom line is that policymakers in the region are entering a new era in which the supply of traditional energy sources will be inadequate to meet the needs of their growing economies and the aspirations of their citizens. They need to act boldly and decisively, and they need to act now.

Skyscrapers around Tokyo Bay at night. With oil consumption almost entirely dependent on imports, the Japanese government is working hard to improve energy security by using more natural gas, nuclear power, and coal. © Michael S. Yamashita/Corbis

Energy Insecurity Index

Kang Wu

Charles E. Morrison

Concerns about energy security in the Asia-Pacific region focus primarily on efforts to secure adequate oil supplies to support economic growth. Policymakers in the United States and Europe face similar challenges.

To illustrate the current situation and changes over time, an energy insecurity index has been developed, based on oil consumption, for selected countries in the Asia-Pacific region and for Europe and the United States. The index is based on the importance of oil in an economy, the dependence on imported oil, and, more specifically, the dependence on oil imported from the Middle East. These three factors are each weighted by a different percentage according to their perceived importance, as follows:

1. Share of net imports in total oil consumption (40 percent weight): Overall dependence on imported oil is considered the most important factor determining oil-related energy insecurity for a country/economy or a region.
2. Share of oil in total primary commercial energy consumption (35 percent weight): The relative importance of oil plays a pivotal role in overall energy security.
3. Share of the Middle East in total oil imports (25 percent weight): Use of this factor might be debatable because overdependence on any region for oil supplies could be a cause for concern. In addition, the oil market is global, so if supplies are disrupted anywhere in the world all importing countries will pay higher prices. Nevertheless, many countries consider diversifying their sources of oil away from the Middle East as a fundamental component of an energy-security strategy.

Other factors—such as strategic oil stockpiling, long-term cooperation between oil producers and consumers, and investments in oil production overseas—are treated as responses to concerns about energy security rather than representing an economy's fundamental energy-security situation. Such factors are thus excluded from the calculation of the index.

Index Table 1 shows the energy insecurity indices for 1995, 2005, and 2015 (projected) for selected economies in the Asia-Pacific region and for Europe and the United States. A low index rating for energy insecurity indicates that an economy is relatively self-sufficient in terms of oil supply. Among economies in the Asia-Pacific region, Brunei Darussalem, Malaysia, and Vietnam had the best energy-insecurity ratings in 2005. Negative index values for these countries indicate that they produced more than enough oil domestically to meet their

HOW IS THE ENERGY INSECURITY INDEX CALCULATED?

To calculate the energy insecurity index for China in 2005, we proceed through the following steps:

1. Oil accounted for 21 percent of China's total primary commercial energy consumption in 2005. Multiplying by 35 percent gives a weighted value of 0.0735.

2. Net imports accounted for 46 percent of China's total oil consumption in 2005. Multiplying by 40 percent gives a weighted value of 0.184.

3. The Middle East accounted for 40 percent of China's total oil imports in 2005. Multiplying by 25 percent gives a weighted value of 0.1.

4. Adding the three weighted values gives a total of 0.3575, or an index value for China in 2005 of 36.

A similar calculation for India in 2005 is as follows:

1. Oil accounted for 30 percent of India's total primary commercial energy consumption in 2005. Multiplying by 35 percent gives a weighted value of 0.105.

2. Net imports accounted for 70 percent of India's total oil consumption in 2005. Multiplying by 40 percent gives a weighted value of 0.28.

3. The Middle East accounted for 71 percent of India's total oil imports in 2005. Multiplying by 25 percent gives a weighted value of 0.1775.

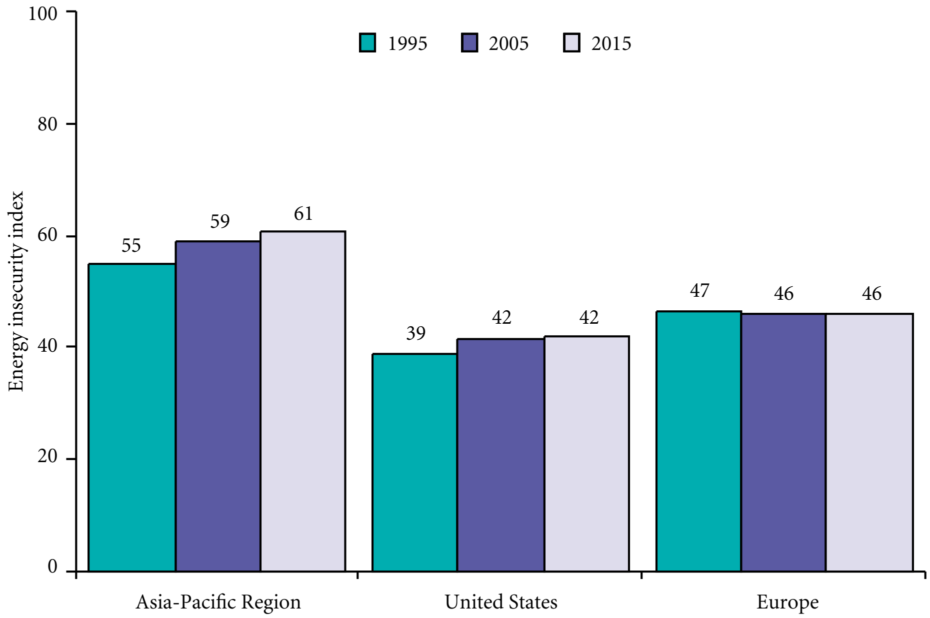
4. Adding the three weighted values gives a total of 0.5625, or an index value for India in 2005 of 56.

Index Table 1. Energy insecurity index, 1995, 2005, and 2015 projected, and change over 10-year periods, selected Asia-Pacific countries/economies, Europe, and the United States

Country/economy	1995	2005	2015 Projected	Change 1995–2005	Projected change 2005–2015
Australia	34.3	33.3	35.2	−1.0	1.9
Bangladesh	57.8	57.9	56.3	0.1	−1.6
Brunei Darussalem	−629.7	−890.0	−599.0	−260.2	291.1
China	12.9	35.8	45.2	22.9	9.4
Democratic People's Republic of Korea	42.2	41.6	42.0	−0.6	0.4
Hong Kong SAR[a]	76.5	76.7	77.0	0.2	0.3
India	47.9	56.3	59.3	8.4	3.0
Indonesia	−14.2	24.6	37.9	38.8	13.3
Japan	77.8	76.7	75.5	−1.1	−1.2
Malaysia	−5.8	−13.7	0.0	−8.0	13.7
Myanmar	43.6	42.6	51.5	−1.0	8.9
Nepal	51.3	64.2	63.4	12.9	−0.8
New Zealand	43.8	52.0	55.6	8.2	3.6
Pakistan	60.3	62.1	60.9	1.8	−1.2
Philippines	76.6	77.4	74.1	0.8	−3.3
Republic of Korea	82.5	76.3	75.2	−6.2	−1.1
Singapore	95.4	89.5	88.7	−5.9	−0.8
Sri Lanka	69.8	85.9	88.0	16.1	2.1
Taiwan	77.5	73.8	73.6	−3.7	−0.2
Thailand	75.3	71.3	71.8	−4.0	0.5
Vietnam	−25.2	−15.3	6.6	9.9	21.9
Other Asia–Pacific	−0.8	51.9	64.3	52.7	12.4
Asia–Pacific Total	55.3	59.0	60.9	3.7	1.9
Europe	46.6	46.0	46.2	−0.6	0.2
United States	38.9	41.6	42.1	2.7	0.5

Source: Compiled by the authors.
Note: Europe includes Albania, Austria, Belgium, Bosnia-Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Gibraltar, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Macedonia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia and Montenegro, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom.
[a] Special Administrative Region.

Index Figure 1. Energy insecurity index for the Asia-Pacific Region, the United States, and Europe 1995, 2005, and 2015



Source: Compiled by the authors.
Note: See note to Index Table 1 for European countries included in the index.

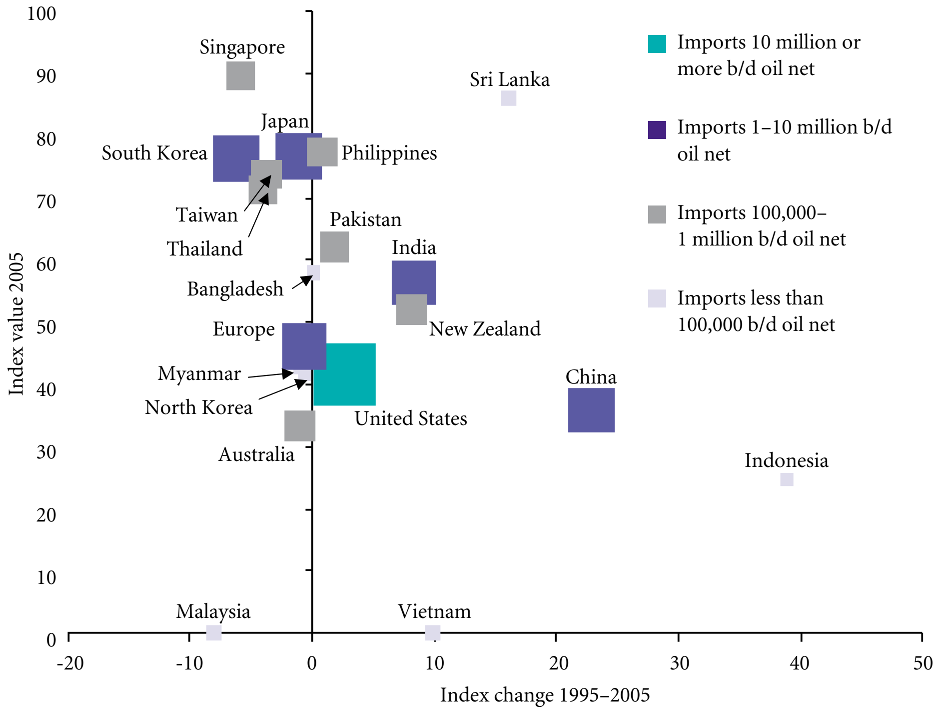
consumption needs. Conversely, a high positive index rating denotes a high degree of dependence on imported oil and thus high energy insecurity. Among Asia-Pacific economies, Singapore had the greatest energy insecurity in 2005 with an index value of 90.

Several interesting observations emerge from these calculations. Already in 1995, the Asia-Pacific region was more insecure in terms of oil supply than was the United States or Europe (Index Figure 1). Energy security in Asia and the Pacific worsened between 1995 and 2005 and is projected to worsen further by 2015.

The largest oil consumer in the world, the United States, became less secure between 1995 and 2005, due to the growing importance of oil in total primary commercial energy consumption and a growing dependence on oil imports (Index Figure 2). Over the next 10 years, however, energy security in the United States is likely to remain stable, with a projected expansion in the share of oil imports offset by a lower share of oil in total primary energy use.

Energy security in Europe lies somewhere between the situation in the United States and the Asia-Pacific region. Between 1995 and 2005, the importance of oil in Europe's total primary commercial energy consumption went down. The share of net imports in Europe's total oil supply went up, but more of Europe's oil imports came from sources outside the Middle East. As a result, the energy-security situation in Europe remained fairly stable. This pattern is likely to continue over the next 10 years. It is worth noting, however, that one of the major energy policy concerns in Europe does not focus on the Middle East at all, but rather relates to dependence on Russia and Central Asia for oil and natural gas.

Index Figure 2. Energy insecurity index (2005) and trends (1995–2005), for selected Asia-Pacific economies, the United States, and Europe



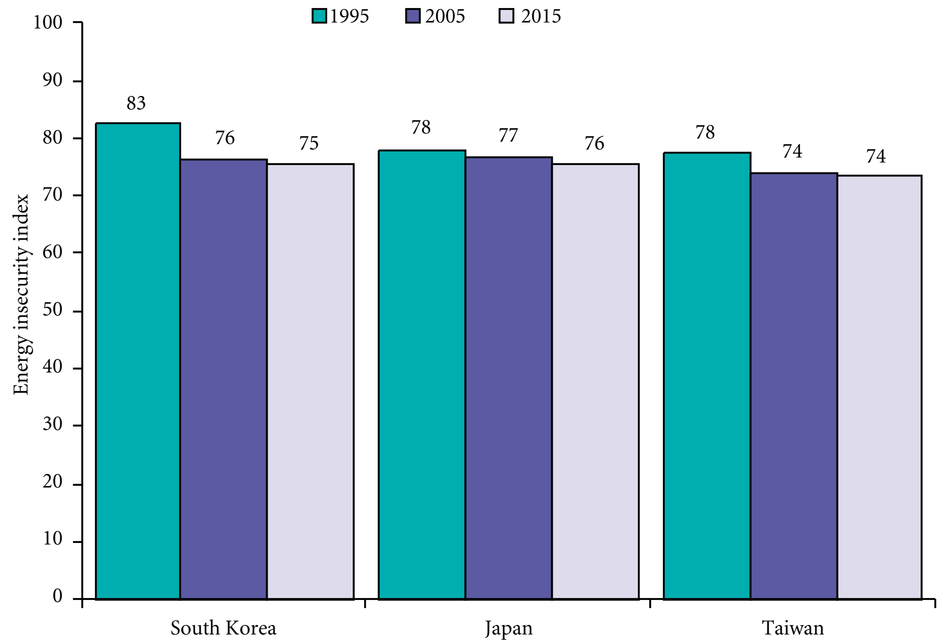
Source: Compiled by the authors.
Note: See note to Index Table 1 for European countries included in the index.

Because the energy-security situation in the United States and Europe is projected to remain fairly stable while security in the Asia-Pacific region is projected to deteriorate, differences between the three regions will widen, with the Asia-Pacific region becoming increasingly less secure than the United States or Europe. The negative trend in Asia and the Pacific results primarily from a very insecure situation in three of the region's most-developed economies, Japan, the Republic of Korea (South Korea), and Taiwan (Index Figure 3), combined with rapidly increasing insecurity in the region's two largest economies, China and India, as well as Indonesia (Index Figure 4).

In 1995, Japan, South Korea, and Taiwan were among the most insecure economies in the region in terms of oil supply after Singapore, which is a special case. Although oil consumption in all three economies is still almost entirely dependent on imports, with a large share from the Middle East, all are managing to stabilize or improve their energy security—even if only slightly—by increasing their use of other energy sources, such as natural gas, nuclear power, and coal.

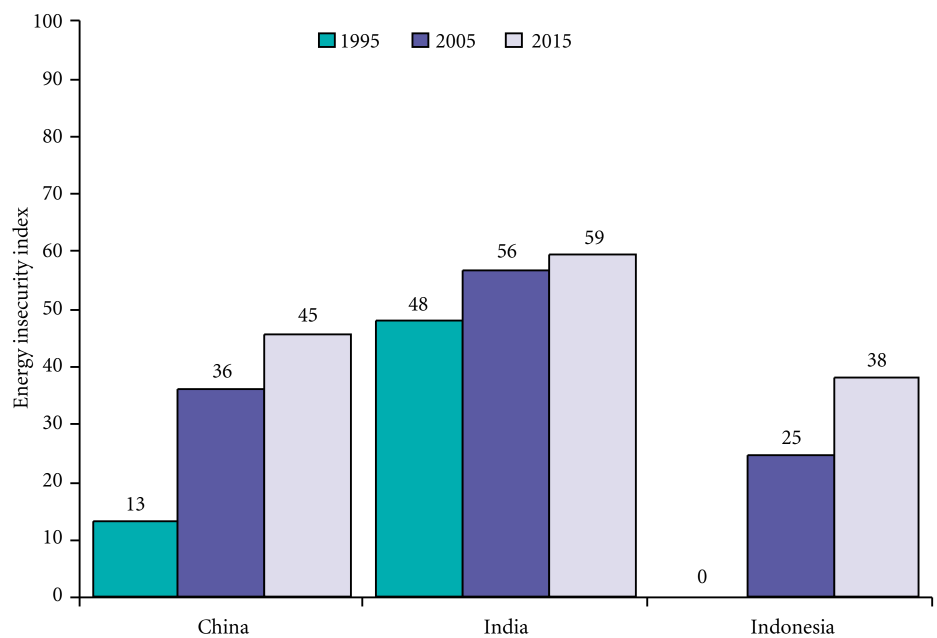
The steepest increases in energy insecurity have been in China and Indonesia (Index Table 1). Indeed, China is projected to surpass the index value for the United States by 2015. The share of oil in China's total primary commercial energy consumption is expected to remain stable over the next 10 years, but oil imports are projected to rise, and the proportion of oil imports from the Middle East is also increasing.

Index Figure 3. Energy insecurity index for South Korea, Japan, and Taiwan, 1995, 2005, and 2015



Source: Compiled by the authors.

Index Index Figure 4. Energy insecurity index for China, India, and Indonesia, 1995, 2005, and 2015



Source: Compiled by the authors.

Indonesia is the only member of the Organization of the Petroleum Exporting Countries (OPEC) in Asia, but it is also the only OPEC member that imports more oil than it exports. In 1995, Indonesia was a net oil exporter, but by 2005, it had become a net oil importer, with a steep rise in energy insecurity. This trend is expected to continue over the next 10 years due to a projected increase in Indonesia's net oil imports.

India was already experiencing relatively high energy insecurity in 1995. By 2005, the share of oil in India's total primary commercial energy consumption had risen significantly, along with the share of imports in India's total oil consumption. As a result, India's index value for energy insecurity increased by 8 points (Index Table 1). Over the next 10 years, the share of oil in India's total primary commercial energy consumption is expected to remain stable, but more oil will be imported, and more imported oil will come from the Middle East, worsening the country's energy security.

Singapore is dependent on oil for 89 percent of primary commercial energy consumption, dependent on imports for 100 percent of its oil supply, and dependent on the Middle East for nearly 75 percent of its oil imports. As a result, Singapore has the highest index value in the region (Index Table 1). The Singaporean government is trying to reduce the country's energy insecurity by switching from oil to other energy sources, particularly natural gas. As a result, Singapore's energy security index value improved between 1995 and 2005 and is projected to improve further—but slightly—by 2015. In terms of dependence on imported oil, however, Singapore will still be the most insecure economy in the region.

Other Asia-Pacific economies with high levels of energy insecurity in 2005 include Bangladesh, Hong Kong, Indonesia, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Taiwan, Thailand, and several smaller countries in the region (combined in Index Table 1 as "Other Asia-Pacific"). All have index ratings of more than 50. The list is projected to remain the same in 2015, with the addition of Myanmar.

Between 2005 and 2015, energy security is projected to deteriorate significantly in Australia, China, India, Indonesia, Myanmar, New Zealand, and several smaller countries of the Asia-Pacific region. By contrast, Bangladesh, Japan, Nepal, Pakistan, the Philippines, Singapore, South Korea, Taiwan, and Thailand are projected to stabilize, or slightly improve, their energy-security status.

In terms of dependence on imported oil, and more specifically on oil imported from the Middle East, the Asia-Pacific region is facing an energy security crisis. By 2015, only two countries in the region—Brunei and Malaysia—will produce enough oil domestically to meet consumption needs. Economies with high dependence on imported oil, such as Japan, South Korea, and Taiwan, will have made little progress in improving their security status. At the same time, energy security will have deteriorated significantly in China, India, and other important economies of the region. Overall, the Asia-Pacific region faces greater energy insecurity than the United States or Europe, and the security gap is projected to increase. This sobering analysis underlines the critical importance of policies to address energy security in the region.

Elevated highways in Shanghai, China. Transportation has been a growing component of overall oil consumption since the 1970s. *© Edward Burtynsky, courtesy Robert Koch Gallery, San Francisco, and Charles Cowles Gallery, New York*

Acknowledgements

This book, *Asia's Energy Future: Regional Dynamics and Global Implications,* brings together a wide range of research on energy conducted by staff members and former staff members of the East-West Center. It is the result of a broad group effort over a period of more than two years.

In addition to the authors of individual chapters, Anna Farina Poerbonegoro (Ph.D. candidate in economics, University of Hawaii at Manoa), Batsaikhan Usukh (Ph.D. in agricultural and resource economics, University of Hawaii at Manoa), Audrey Hao Fang (Ph.D. candidate in economics, University of California at Irving), Daniel Nieh (B.A. in Asian and Middle Eastern studies, University of Pennsylvania), and Shi Fu (Ph.D. candidate in economics, University of Hawaii at Manoa) assisted with data collection, updating, and analysis. Gayle Sueda (Secretary, East-West Center Research Program) read and edited early drafts of the chapters and provided secretarial support. Jane Diehl (student intern, East-West Center) prepared the index.

Charles E. Morrison (President of the East-West Center), Richard Baker (Special Assistant to the President, East-West Center), and Nancy Lewis (Director of Research, East-West Center) provided invaluable scholarly input and support throughout the project. Tilaklal K. Doshi (Executive Director for Energy, Dubai Metals and Commodities Center) and Ronald D. Ripple (Associate Professor of Economics, Macquarie University) provided very useful reviews of the final draft. Responsibility for any errors or omissions, however, rests solely with the chapter authors.

For more than two decades, the U.S. Department of Energy (DOE) and Energy Information Administration (EIA) have provided invaluable support for building the knowledge base and reputation of the energy economics group at the East-West Center. We have owed thanks to many people at the DOE over the years, but we would like to acknowledge in particular the support of the Office of Fossil Energy—specifically James Slutz, Ann Ducca, and Stewart Cedres—and the support of the Office of Policy and International Affairs—specifically David Pumphrey and Jane Nakano. At EIA, we would like to acknowledge the work of Guy Caruso, Glen Sweetnam, and Linda Doman.

Much of the numerical data used in this book was provided by FACTS Global Energy, an international consulting firm specializing in the oil and gas sector and focusing primarily on the Asia-Pacific region.

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Appendix: Forecasting Methodology

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The forecasts presented in this report use a framework that allows the income elasticity of energy demand to change with income, according to a methodology developed by Medlock and Soligo (2001). The objective is to model how energy intensity changes in the major economic sectors as an economy grows.

The model

In this model, energy consumption, $e_{t,j}$, in a particular time period, t, and sector of the economy, j, is a function of per-capita output, y_t, and technology, τ_t, so

$$e_{t,j} = f(y_t, \tau_t) \tag{1}$$

Assuming that technology is a function of economic development, the function can be redefined such that

$$e_{t,j} = f(y_t, \tau(y_t)) = f^*(y_t) \tag{2}$$

It should be noted that this specification does not include energy prices. While this may introduce some bias, the availability of detailed price data is somewhat limited, so a decision was made to include a more complete panel of Asia-Pacific countries at the expense of a price variable (Medlock and Soligo 2001).

To allow for non-constant income elasticity of energy demand, it is assumed that the demand function is of the form

$$e_{t,j} = A y_t^{\, b_1 + b_2 \ln y_t} \tag{3}$$

A logarithmic transformation yields

$$\ln e_{t,j,i} = (\alpha_{j,i} + \theta_{t,j}) + b_1 \ln y_{t,i} + b_2 (\ln y_{t,i})^2 \tag{4}$$

The variable A has been replaced by the term $(\alpha_{j,i} + \theta_{t,j})$, where i represents a specific country and $\alpha_{j,i}$ and $\theta_{t,j}$ represent a country-specific and time-specific effect, respectively (Medlock and Soligo 2001).

Equation 4 represents the long-term relationship between energy consumption and income. The corresponding long-term income elasticity is

$$b_1 + 2b_2(\ln y_{t,i}) \tag{5}$$

which will decline as income rises, as long as $b_1 > 0$ and $b_2 < 0$. This implies that per-capita energy consumption peaks at a certain level of income and then begins to decline with income, which is unlikely. It is more likely that growth in per-capita energy consumption slows as the economy continues to grow, and thus equation 5 should be considered an approximation of the relationship between energy consumption and income (Medlock and Soligo 2001).

Figure 1 illustrates a possible growth path for sectoral energy consumption in a hypothetical Asia-Pacific nation. This hypothetical growth path is derived from the forecasting framework and a set of data for Asia and the Pacific. In general, a variation of this forecasting framework provides the basis for all of the projections included in this report, unless otherwise sourced or specified.

The Asia-Pacific data set

The Asia-Pacific data set used to model the energy consumption path of a hypothetical country includes information from 13 countries over the period 1970 to 1998. These are Australia, Bangladesh, China, India, Indonesia, Japan, Malaysia, New Zealand, Pakistan, the Philippines, the Republic of Korea, Sri Lanka, and Thailand. The energy data are taken from the International Energy Agency (OECD/IEA 2004a; OECD/IEA 2004b), where energy consumption is defined as final energy consumption in each end-use sector (excluding biomass)—residential/commercial, transportation, and industrial. The International Energy Agency (OECD/IEA 2004a; OECD/IEA 2004b), is also the source of information on total final electricity consumption. The unit of measurement is barrels of oil equivalent per day, which is comparable across fuels and countries.

To allow comparisons across countries, a purchasing-power-parity (PPP) measure of per-capita gross domestic product (GDP) is used. This is obtained from the Penn World Tables (Summers and Heston 1995) and is denominated in 1985 international dollars. Missing data are calculated from the 1985 GDP per capita and the GDP per-capita growth rates presented by the World Bank (2003). Population data are drawn from the same source.

Future real GDP growth is forecast using projections from the International Monetary Fund and the East-West Center. This forecast is adjusted for population growth using projections from the United Nations (2002), to yield a projection of real GDP growth per capita.

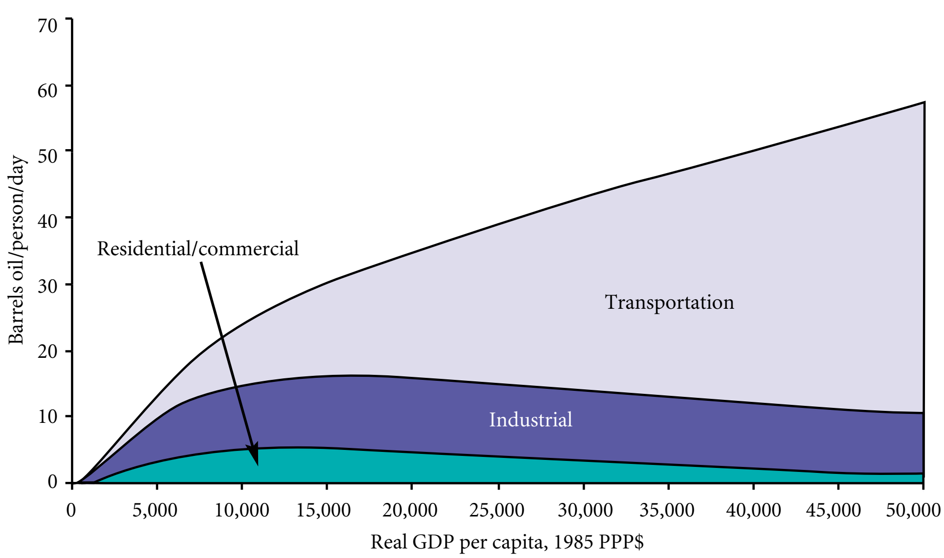

Figure 1. Changes in sectoral energy consumption with growth in real GDP per capita for a hypothetical Asia-Pacific nation

Source: Authors' models.

Appendix Tables

Appendix Table 1.1. Annual primary commercial energy consumption from five major sources, selected Asia-Pacific countries/economies, 2005 actual and 2015 projected (thousand barrels of oil equivalent per day: boe/d), and annual percentage change

	Oil[a]			Natural gas			Coal		
Country/economy	2005 (thousand boe/d)	2015 (thousand boe/d)	Annual change 2005–2015 (%)	2005 (thousand boe/d)	2015 (thousand boe/d)	Annual change 2005–2015 (%)	2005 (thousand boe/d)	2015 (thousand boe/d)	Annual change 2005–2015 (%)
Australia	794	926	1.6	470	625	2.9	1,044	1,215	1.5
Bangladesh	80	118	3.9	222	408	6.3	9	26	11.5
Brunei Darussalam	9	12	2.9	41	71	5.6	—	—	—
China	6,476	10,526	5.0	870	2,487	11.1	21,646	32,672	4.2
Democratic People's Republic of Korea	18	23	2.7	—	—	—	332	341	0.2
Hong Kong SAR[b]	276	335	2.0	52	103	7.1	144	141	-0.2
India	2,314	3,251	3.5	708	1,675	9.0	4,258	5,294	2.2
Indonesia	1,106	1,439	2.7	725	1,066	3.9	470	500	0.6
Japan	4,884	4,742	-0.3	1,383	1,607	1.5	2,426	2,446	0.1
Malaysia	440	601	3.2	482	570	1.7	126	161	2.5
Myanmar	36	67	6.3	23	39	5.5	1	1	0.3
Nepal	14	20	3.5	—	—	—	4	7	5.5
New Zealand	140	165	1.7	70	80	1.3	43	25	-5.2
Pakistan	348	457	2.8	549	884	4.9	82	123	4.2
Philippines	294	352	1.8	58	151	10.0	118	171	3.7
Republic of Korea	2,110	2,434	1.4	548	820	4.1	1,100	1,807	5.1
Singapore	844	1,092	2.6	105	170	5.0	—	—	—
Sri Lanka	70	112	4.8	—	—	—	1	1	0.5
Taiwan	832	1,095	2.8	224	413	6.3	763	1,001	2.8
Thailand	912	1,190	2.7	482	830	5.6	234	264	1.2
Vietnam	195	328	5.4	96	303	12.2	136	325	9.1
Other Asia-Pacific	80	110	3.2	3	4	2.0	25	27	1.0
Total Asia-Pacific	22,272	29,395	2.8	7,110	12,306	5.6	32,961	46,546	3.5
World	77,494	92,894	1.8	49,280	69,836	3.5	58,595	72,200	2.3
Share of Asia-Pacific in world (%)	28.7	31.6		14.4	17.6		56.3	64.5	

Sources: BP (2006); EIA (2006); FACTS Global Energy (2006).
Notes: Entries might not add up exactly to totals due to rounding. Data for 2015 are projections.
[a] Oil consumption is measured in barrels of oil equivalent per day to facilitate comparison with consumption of other energy sources. Figures for consumption of barrels of oil per day are slightly different. See Appendix Tables 3.1 and 3.2.
[b] Special Administrative Region.

Hydropower			Nuclear power			Total consumption		
2005 (thousand boe/d)	2015 (thousand boe/d)	Annual change 2005–2015 (%)	2005 (thousand boe/d)	2015 (thousand boe/d)	Annual change 2005–2015 (%)	2005 (thousand boe/d)	2015 (thousand boe/d)	Annual change 2005–2015 (%)
74	78	0.6	—	—	—	2,382	2,845	1.8
6	10	5.8	—	—	—	316	561	5.9
—	—	—	—	—	—	50	82	5.2
1,829	3,882	7.8	240	1,228	17.7	31,062	50,794	5.0
52	54	0.2	—	—	—	402	418	0.4
—	—	—	—	—	—	472	579	2.1
434	716	5.1	80	266	12.7	7,794	11,202	3.7
43	80	6.3	—	—	—	2,344	3,085	2.8
396	423	0.7	1,326	1,516	1.3	10,415	10,734	0.3
31	34	1.2	—	—	—	1,079	1,366	2.4
13	32	9.2	—	—	—	74	139	6.6
12	18	4.7	—	—	—	29	45	4.3
110	138	2.3	—	—	—	363	408	1.2
139	237	5.5	6	10	5.5	1,122	1,710	4.3
39	53	3.3	—	—	—	509	727	3.6
24	40	5.2	652	829	2.4	4,434	5,930	2.9
—	—	—	—	—	—	949	1,262	2.9
15	17	1.5	—	—	—	86	130	4.3
36	49	3.2	180	260	3.7	2,035	2,819	3.3
28	48	5.5	—	—	—	1,656	2,334	3.5
90	187	7.6	—	—	—	517	1,143	8.3
27	32	2.0	—	—	—	135	173	2.5
3,396	6,129	6.1	2,485	4,108	5.2	68,224	98,485	3.7
12,487	14,617	3.2	12,912	13,421	0.4	210,769	262,968	2.2
27.2	41.9		19.2	30.6		32.4	37.5	

Appendix Table 1.2. Population of Asia-Pacific countries/economies, mid-2005 actual and 2050 projected (millions)

Country/economy	Population (millions) Mid-2005	Population (millions) 2050 projected	Country/economy	Population (millions) Mid-2005	Population (millions) 2050 projected
South Asia			**East Asia (continued)**		
Afghanistan	29.9	81.9	Macao SAR[a]	0.5	0.5
Bangladesh	144.2	231.0	Mongolia	2.6	3.9
Bhutan	1.0	2.0	Republic of Korea	48.3	42.3
India	1,103.6	1,628.0	Taiwan	22.7	19.8
Maldives	0.3	0.5	East Asia subtotal	1,535.3	1,639.3
Nepal	25.4	47.8			
Pakistan	162.4	295.0	**Pacific**		
Sri Lanka	19.7	22.4	Australia	20.4	26.3
South Asia subtotal	1,486.5	2,308.6	Federated States of Micronesia	0.1	0.1
			Fiji	0.8	0.9
Southeast Asia			French Polynesia	0.3	0.4
Brunei Darussalam	0.4	0.6	Guam	0.2	0.2
Cambodia	13.3	24.6	Kiribati	0.1	0.2
Timor-Leste	0.9	3.3	Marshall Islands	0.1	0.1
Indonesia	221.9	308.4	Nauru	0.0	0.0
Lao People's Democratic Republic	5.9	11.6	New Caledonia	0.2	0.4
Malaysia	26.1	47.0	New Zealand	4.1	5.0
Myanmar	50.5	63.7	Palau	0.0	0.0
Philippines	84.8	142.2	Papua New Guinea	5.9	10.6
Singapore	4.3	5.2	Samoa	0.2	0.2
Thailand	65.0	73.2	Solomon Islands	0.5	0.9
Vietnam	83.3	115.4	Tonga	0.1	0.2
Southeast Asia subtotal	556.4	795.2	Tuvalu	0.0	0.0
			Vanuatu	0.2	0.4
East Asia			Pacific subtotal	33.2	46.0
China	1,303.7	1,437.0			
Democratic People's Republic of Korea	22.9	26.4	Total Asia-Pacific	3,611.4	4,789.1
Hong Kong SAR[a]	6.9	8.8	World	6,477.0	9,262.0
Japan	127.7	100.6	Share of Asia-Pacific in world (%)	55.8	51.7

Source: PRB (2005).
[a] Special Administrative Region.

Appendix Table 1.3. Annual per-capita primary commercial energy consumption from five major sources, selected Asia-Pacific countries/economies, 2005 (barrels of oil equivalent: boe)

	Annual per-capita primary commercial energy consumption (boe)					
Country/economy	Oil	Natural gas	Coal	Hydro-power	Nuclear power	Total
Australia	14.21	8.41	18.68	1.32	—	42.62
Bangladesh	0.20	0.56	0.02	0.01	—	0.80
Brunei Darussalam	7.99	37.43	—	—	—	45.43
China	1.81	0.24	6.06	0.51	0.07	8.70
Democratic People's Republic of Korea	0.29	—	5.30	0.83	—	6.41
Hong Kong SAR[a]	14.60	2.73	7.62	0.00	—	24.95
India	0.77	0.23	1.41	0.14	0.03	2.58
Indonesia	1.82	1.19	0.77	0.07	—	3.86
Japan	13.96	3.95	6.93	1.13	3.79	29.77
Malaysia	6.15	6.74	1.76	0.43	—	15.09
Myanmar	0.26	0.17	0.01	0.10	—	0.53
Nepal	0.20	—	0.06	0.17	—	0.42
New Zealand	12.46	6.24	3.79	9.80	—	32.29
Pakistan	0.78	1.23	0.18	0.31	0.01	2.52
Philippines	1.27	0.25	0.51	0.17	—	2.19
Republic of Korea	15.95	4.14	8.31	0.18	4.93	33.51
Singapore	71.64	8.88	—	—	—	80.52
Sri Lanka	1.29	—	0.02	0.28	—	1.59
Taiwan	13.38	3.60	12.27	0.58	2.90	32.72
Thailand	5.12	2.70	1.31	0.16	—	9.30
Vietnam	0.85	0.42	0.60	0.39	—	2.26
Others	0.47	0.02	0.14	0.15	—	0.78
Total Asia-Pacific	2.25	0.72	3.33	0.34	0.25	6.90
World	4.37	2.78	3.30	0.73	0.70	11.88

Sources: BP (2006); FACTS Global Energy (2006); PRB (2005).
Notes: Entries might not add up exactly to totals due to rounding. Calculations are based on population estimates as of mid-2005.
[a] Special Administrative Region.

Appendix Table 1.4. Average annual growth rate of real gross domestic product (GDP) and primary commercial energy consumption, selected Asia-Pacific countries/economies, the European Union, and the United States, 1980–2005 (percent)

Country/economy	Average annual growth rate, 1980–2005 (percent)	
	Real GDP	Primary commercial energy consumption
Australia	3.4	2.4
Bangladesh	4.5	7.2
Brunei	1.1	-0.1
China	9.6	5.3
Hong Kong SAR[a]	5.3	5.5
India	5.8	5.5
Indonesia	4.7	6.4
Japan	2.4	1.5
Malaysia	6.1	7.2
Myanmar	5.1	3.2
Nepal	4.5	8.6
New Zealand	2.8	2.3
Pakistan	4.9	5.9
Philippines	2.7	3.5
Republic of Korea	6.8	7.2
Singapore	6.8	6.6
Sri Lanka	4.6	4.3
Taiwan	6.3	5.7
Thailand	5.9	8.2
Vietnam	6.8	7.9
Total Asia-Pacific	4.2	4.4
European Union	2.1	0.6
United States	3.2	1.0

Sources: IMF (2006); OECD/IEA (2006); FACTS Global Energy (2006).
[a] Special Administrative Region.

Appendix Table 1.5. Share of primary commercial energy consumption from five major sources, selected Asia-Pacific countries/economies, 2005 (percent)

	Share of primary commercial energy consumption (percent)					
Country/economy	Oil	Natural gas	Coal	Hydro-power	Nuclear power	Total
Australia	33.3	19.7	43.8	3.1	0.0	100
Bangladesh	25.3	70.2	2.8	1.7	0.0	100
Brunei Darussalam	17.6	82.4	0.0	0.0	0.0	100
China	20.8	2.8	69.7	5.9	0.8	100
Democratic People's Republic of Korea	4.4	0.0	82.6	13.0	0.0	100
Hong Kong SAR[a]	58.5	11.0	30.5	0.0	0.0	100
India	29.7	9.1	54.6	5.6	1.0	100
Indonesia	47.2	30.9	20.1	1.8	0.0	100
Japan	46.9	13.3	23.3	3.8	12.7	100
Malaysia	40.8	44.7	11.7	2.8	0.0	100
Myanmar	49.6	31.1	1.4	17.9	0.0	100
Nepal	47.6	0.0	13.2	39.2	0.0	100
New Zealand	38.6	19.3	11.7	30.3	0.0	100
Pakistan	31.0	48.9	7.3	12.3	0.5	100
Philippines	57.7	11.5	23.2	7.6	0.0	100
Republic of Korea	47.6	12.4	24.8	0.5	14.7	100
Singapore	89.0	11.0	0.0	0.0	0.0	100
Sri Lanka	81.2	0.0	1.3	17.5	0.0	100
Taiwan	40.9	11.0	37.5	1.8	8.9	100
Thailand	55.1	29.1	14.1	1.7	0.0	100
Vietnam	37.7	18.5	26.3	17.4	0.0	100
Others	59.5	2.6	18.2	19.7	0.0	100
Total Asia-Pacific	32.6	10.4	48.3	5.0	3.6	100
World	36.8	23.4	27.8	5.9	6.1	100

Source: FACTS Global Energy (2006).
[a] Special Administrative Region.

Appendix Table 1.6. Primary commercial energy production from five major sources, selected Asia-Pacific countries/economies, 2005 (thousand barrels of oil equivalent per day: boe/d)

	Primary commercial energy production (thousand boe/d)					
Country/economy	Oil	Natural gas	Coal	Hydro-power	Nuclear power	Total
Australia	400	668	4,048	74	0	5,190
Bangladesh	7	256	0	6	0	268
Brunei Darussalam	194	216	0	0	0	410
China	3,607	900	22,154	1,829	240	28,731
India	597	548	3,992	434	80	5,651
Indonesia	1,027	1,368	1,664	43	0	4,102
Japan	13	0	0	396	1,326	1,735
Malaysia	694	1,080	4	31	0	1,808
Myanmar	25	180	0	13	0	219
New Zealand	18	66	64	110	0	258
Pakistan	60	538	32	139	6	775
Philippines	17	65	23	39	0	144
Republic of Korea	0	6	0	24	652	682
Taiwan	1	14	0	36	180	231
Thailand	150	386	118	28	0	682
Vietnam	361	92	366	90	0	909
Others	50	0	431	105	0	586
Total Asia-Pacific	7,221	6,383	32,896	3,396	2,485	52,382
World	76,965	48,668	55,020	12,487	12,912	206,053
Share of Asia-Pacific in world (%)	9.4	13.1	59.8	27.2	19.2	25.4

Source: FACTS Global Energy (2006).

Appendix Table 1.7. Share of primary commercial energy production from five major sources, selected Asia-Pacific countries/economies, 2005 (percent)

	Share of primary commercial energy production (percent)					
Country/economy	Oil	Natural gas	Coal	Hydro-power	Nuclear power	Total
Australia	7.7	12.9	78.0	1.4	0.0	100
Bangladesh	2.5	95.4	0.0	2.1	0.0	100
Brunei Darussalam	47.4	52.6	0.0	0.0	0.0	100
China	12.6	3.1	77.1	6.4	0.8	100
India	10.6	9.7	70.6	7.7	1.4	100
Indonesia	25.0	33.4	40.6	1.1	0.0	100
Japan	0.8	0.0	0.0	22.8	76.4	100
Malaysia	38.4	59.7	0.2	1.7	0.0	100
Myanmar	11.5	82.5	0.0	6.0	0.0	100
New Zealand	7.1	25.6	24.8	42.6	0.0	100
Pakistan	7.8	69.4	4.1	17.9	0.7	100
Philippines	12.0	45.3	15.9	26.8	0.0	100
Republic of Korea	0.0	0.9	0.0	3.5	95.6	100
Taiwan	0.4	5.9	0.0	15.5	78.2	100
Thailand	21.9	56.6	17.3	4.2	0.0	100
Vietnam	39.7	10.1	40.3	9.9	0.0	100
Others	8.5	0.0	73.5	18.0	0.0	100
Total Asia-Pacific	13.8	12.2	62.8	6.5	4.7	100
World	37.4	23.6	26.7	6.1	6.3	100

Sources: BP (2006); FACTS Global Energy (2006).

Appendix Table 1.8. Estimated oil, natural-gas, and coal reserves and reserve-to-production (R/P) ratios, selected Asia-Pacific countries/economies, end of 2005

	Oil		Natural gas		Coal	
Country/economy	Reserves (billion barrels)	R/P ratio[a] (years)	Reserves (trillion cubic feet)	R/P ratio[a] (years)	Reserves (million tonnes)	R/P ratio[a] (years)
Australia	4.0	20.0	89.0	67.9	78,500	213
Bangladesh	0.0	11.0	15.4	30.7	—	—
Brunei Darussalam	1.1	14.9	12.0	28.3	—	—
China	16.0	12.1	83.0	47.0	114,500	52
Democratic People's Republic of Korea	—	—	—	—	600	20
India	5.9	20.7	38.9	36.2	92,445	217
Indonesia	4.3	10.4	97.4	36.3	4,968	37
Japan	0.1	9.0	—	—	359	323
Malaysia	4.2	13.9	87.5	41.4	4	11
Myanmar	0.1	5.1	17.7	38.5	2	2
New Zealand	0.1	7.4	0.9	6.0	571	111
Pakistan	0.3	12.2	34.0	32.2	3,050	871
Papua New Guinea	0.2	12.2	15.1	>1,000.0	—	—
Republic of Korea	—	—	—	—	80	28
Thailand	0.5	5.2	12.5	16.5	1,354	64
Vietnam	3.1	21.8	8.3	45.6	150	5
Others	0.1	19.6	12.2	52.7	312	27
Total Asia-Pacific	40.0	14.6	523.7	41.2	296,889	92
World	1,200.7	40.6	6,348.1	65.1	909,064	155
Share of Asia-Pacific in world (%)	3.4		8.3		32.7	

Sources: BP (2006); *Oil & Gas Journal* (2005).
Note: Entries might not add up exactly to totals due to rounding.
[a] The reserve-to-production (R/P) ratio is the reserves remaining at the end of 2005 divided by production in 2005. The result is an estimated number of years that existing reserves can be expected to last if production continues at the same rate and no new reserves are discovered.

Appendix Table 2.1. Coal consumption in selected Asia-Pacific countries/economies (thousand barrels of oil equivalent per day: boe/d), 1980, 2005, and 2015, and average annual growth rate (percent), 1980–2005 and 2005–2015

Country/economy	Annual consumption (thousand boe/d)			Average annual growth rate (percent)	
	1980	2005	2015	1980–2005	2005–2015
Australia	522	1,044	1,215	2.8	1.5
Bangladesh	2	9	26	5.2	11.5
China	6,251	21,646	32,672	5.1	4.2
Democratic People's Republic of Korea	512	332	341	-1.7	0.2
Hong Kong SAR[a]	0	144	141	32.8	-0.2
India	1,142	4,258	5,294	5.4	2.2
Indonesia	6	470	500	19.1	0.6
Japan	1,152	2,426	2,446	3.0	0.1
Malaysia	1	126	161	22.3	2.5
Myanmar	3	1	1	-4.1	0.3
Nepal	1	4	7	5.0	5.5
New Zealand	20	43	25	3.0	-5.2
Pakistan	15	82	123	6.9	4.2
Philippines	7	118	171	11.8	3.7
Republic of Korea	264	1,100	1,807	5.9	5.1
Sri Lanka	0	1	1	17.6	0.5
Taiwan	78	763	1,001	9.6	2.8
Thailand	9	234	264	13.7	1.2
Vietnam	45	136	325	4.5	9.1
Others	3	25	27	8.5	1.0
Total Asia-Pacific	10,035	32,961	46,546	4.9	3.5

Sources: BP (2006); FACTS Global Energy (2006).
Note: Data for 2015 are forecasts.
[a] Special Administrative Region.

Appendix Table 2.2. Consumption of combustible renewable and waste energy (thousand barrels of oil equivalent per day: boe/d) and share of renewable and waste sources in total primary energy consumption (PEC) (percent), selected Asia-Pacific countries, 1980, 1990, and 2003

Country	Consumption of combustible renewable and waste energy (thousand boe/d)			Share in total PEC[a] (percent)		
	1980	1990	2003	1980	1990	2003
Australia	72	79	100	5	4	4
Bangladesh	113	137	160	67	53	37
China	3,599	4,008	4,379	30	22	16
India	2,963	3,516	4,224	59	48	38
Indonesia	593	746	867	53	40	27
Malaysia	32	42	52	14	9	5
Myanmar	151	180	201	80	84	74
Nepal	88	109	152	95	92	84
New Zealand	11	14	18	4	4	4
Democratic People's Republic of Korea	17	19	20	3	3	5
Pakistan	281	375	517	53	42	34
Philippines	140	153	206	36	30	24
Sri Lanka	62	78	80	63	63	46
Thailand	213	293	294	47	33	16
Vietnam	306	378	458	78	76	49
Others	125	168	319	1	1	2
Total Asia-Pacific	8,765	10,297	12,048	28	23	17

Sources: Calculated from OECD/IEA (2005a; 2005b).
Note: Entries may not add to totals exactly due to rounding.
[a] Primary energy consumption includes commercial and non-commercial energy.

Appendix Table 3.1. Oil production, consumption, and net surplus/deficit (thousand barrels per day: b/d) and dependence on imports (percent of total consumption), selected Asia-Pacific countries/economies, 2005

Country/economy	Production (thousand b/d)	Consumption (thousand b/d)	Net surplus/deficit (thousand b/d)	Dependence on imports (percent total consumption)
Australia	421	828	-407	49
Bangladesh	7	88	-81	92
Brunei Darussalam	199	11	188	—
China	3,617	6,431	-2,862	44
Democratic People's Republic of Korea	0	23	-23	100
Hong Kong SAR[a]	0	287	-287	100
India	645	2,384	-1,739	73
Indonesia	1,061	1,243	-182	15
Japan	14	5,066	-5,052	100
Malaysia	780	537	243	—
Myanmar	27	46	-19	41
Nepal	0	18	-18	100
New Zealand	20	147	-127	87
Pakistan	65	295	-230	78
Papua New Guinea	54	21	33	—
Philippines	19	299	-281	94
Republic of Korea	0	2,237	-2,237	100
Singapore	0	755	-755	100
Sri Lanka	0	88	-88	100
Taiwan	1	948	-947	100
Thailand	184	970	-786	81
Vietnam	371	246	126	—
Other Asia-Pacific	0	80	-80	100
Total Asia-Pacific	7,485	23,048	-15,611	68

Source: FACTS Global Energy (2006).
Note: Entries might not add or subtract to totals exactly due to rounding.
[a] Special Administrative Region.

Appendix Table 3.2. Oil consumption (thousand barrels per day: b/d), selected Asia-Pacific countries/economies, 1970–2015, and average annual increase, 1970–2005 and 2005–2015

	Oil consumption (thousand b/d)							Average annual increase (%)	
Country/economy	1970	1980	1990	2000	2005	2010	2015	1970–2005	2005–2015
Australia	469	601	660	762	828	895	966	1.6	1.6
Bangladesh	13	31	36	64	88	107	130	5.5	3.9
Brunei Darussalam	1	4	6	9	11	13	15	6.1	2.9
China	545	1,614	2,205	4,565	6,431	8,549	10,434	7.3	5.0
Democratic People's Republic of Korea	14	49	43	20	23	25	29	1.4	2.7
Hong Kong SAR[a]	73	126	135	245	287	327	349	4.0	2.0
India	390	616	1,119	2,158	2,384	2,848	3,350	5.3	3.5
Indonesia	149	405	603	1,051	1,243	1,398	1,617	6.3	2.7
Japan	4,126	4,896	5,174	5,427	5,066	4,961	4,918	0.6	-0.3
Malaysia	81	158	264	460	537	637	732	5.6	3.2
Myanmar	19	25	13	35	46	66	85	2.6	6.3
Nepal	1	2	5	15	18	21	25	8.5	3.5
New Zealand	78	86	99	126	147	161	173	1.8	1.7
Pakistan	62	98	205	364	295	339	388	4.6	2.8
Papua New Guinea	3	8	17	20	21	24	27	5.6	2.4
Philippines	145	196	208	329	299	329	359	2.1	1.8
Republic of Korea	173	505	1,021	2,156	2,237	2,431	2,581	7.6	1.4
Singapore	78	173	407	642	755	907	977	6.7	2.6
Sri Lanka	24	30	31	73	88	114	141	3.8	4.8
Taiwan	123	368	549	863	948	1,101	1,248	6.0	2.8
Thailand	104	223	401	775	970	1,093	1,266	6.6	2.7
Vietnam	125	33	53	157	246	325	414	1.9	5.4
Others	28	37	52	65	80	95	111	3.1	3.4
Total Asia-Pacific	6,825	10,284	13,308	20,382	23,048	26,766	30,335	3.5	2.8

Source: FACTS Global Energy (2006).
Note: Data for 1970–2005 are actual, and data for 2010 and 2015 are forecasts. Entries might not add up exactly to totals due to rounding.
[a] Special Administrative Region.

Appendix Table 3.3. Petroleum refining capacity and consumption of petroleum products (thousand barrels per day: b/d), selected Asia-Pacific countries/economies, 2005

Country/economy	Refining capacity at end of 2005 (thousand b/d)	Annual domestic consumption, 2005 (thousand b/d)
Australia	718	828
Bangladesh	31	88
Brunei Darussalam	12	11
China	6,459	6,431
Democratic People's Republic of Korea	69	23
India	2,651	2,384
Indonesia	1,106	1,243
Japan	4,436	5,066
Malaysia	522	537
Myanmar	57	46
New Zealand	95	147
Pakistan	272	295
Papua New Guinea	33	21
Philippines	292	299
Republic of Korea	2,579	2,237
Singapore	1,299	755
Sri Lanka	45	88
Taiwan	1,237	948
Thailand	1,049	970
Vietnam	5	246
Others	0	384
Total Asia-Pacific	22,967	23,048

Source: FACTS Global Energy (2006).
Note: Refining capacity is usually referred to in terms of crude distillation units, or CDU, and is commonly measured as barrels per calendar day.

Appendix Table 3.4. International trade in petroleum products (thousand barrels per day: b/d), selected Asia-Pacific countries/economies, 2005 and 2010 projected

Country/economy	Trade in 2005 (thousand b/d)			Trade in 2010 (thousand b/d)		
	Exports	Imports	Net surplus/deficit	Exports	Imports	Net surplus/deficit
Australia	122	206	-83	71	195	-124
China	353	849	-495	171	980	-808
India	433	257	176	1,047	126	922
Indonesia	172	478	-305	137	390	-253
Japan	157	1,054	-897	174	953	-779
Malaysia	122	142	-20	150	200	-50
Pakistan	26	106	-80	61	83	-22
Philippines	29	114	-85	20	146	-125
Republic of Korea	720	491	229	752	644	108
Singapore	1,380	963	417	1,325	1,022	303
Taiwan	321	176	145	340	230	110
Thailand	149	99	50	152	138	15
Vietnam	1	236	-235	0	190	-190
Other	43	599	-555	43	721	-678
Total Asia-Pacific	4,030	5,769	-1,740	4,443	6,016	-1,573

Source: FACTS Global Energy (2006).
Note: Data for 2005 are preliminary, and data for 2010 are forecasts.

Appendix Table 3.5. Trend in oil demand, supply, and net imports (million barrels per day: b/d) and dependence on imports (percent), Asia-Pacific region, 2000–2010

	2000	2002	2005	2006	2008	2010
Oil demand (million b/d)[a]	20.8	20.8	23.2	24.0	25.3	27.0
Oil supply (million b/d)[b]	7.8	7.8	7.8	8.1	8.6	8.6
Net imports (million b/d)	13.0	13.0	15.4	15.9	16.8	18.4
Dependence on imports (%)	63	62	66	66	66	68

Source: FACTS Global Energy (2006).
Note: Data for 2000 and 2002 are actual, data for 2005 are preliminary, and data for 2006–2010 are forecasts. Entries might not add up exactly to totals due to rounding.
[a] Crude oil refined and consumed directly, plus non-refinery liquefied petroleum gas (LPG)/naphtha, plus net imports of petroleum products. This definition is slightly different from oil consumption.
[b] Crude oil plus nonrefinery LPG/naphtha produced, which is slightly higher than crude oil producton alone.

Appendix Table 3.6. Crude oil imports (million barrels per day: b/d)and share from the Middle East (percent), Asia-Pacific region, 2000–2010

	2000	2002	2005	2006	2008	2010
Total imports (million b/d)	13.1	12.9	15.6	16.2	17.3	18.8
From Middle East	9.7	9.3	11.4	12.0	12.9	14.3
From within region	1.8	1.9	1.7	1.8	1.8	1.8
From outside region, not Middle East	1.5	1.7	2.4	2.4	2.6	2.8
Middle-East share of total (%)	74	72	73	74	75	76
Middle-East share of total outside region (%)	86	85	83	83	83	84

Source: FACTS Global Energy (2006).
Note: Data for 2000 and 2002 are actual, data for 2005 are preliminary, and data for 2006–2010 are forecasts. Entries might not add up exactly to totals due to rounding.

Appendix Table 4.1. Natural-gas production, consumption by economic sector, imports, and exports in the Asia-Pacific region, 1975–2015 (million standard cubic feet per day: scf/d)

Year	Production (million scf/d)	Consumption (million scf/d)						Imports[b] (million scf/d)	Exports[b] (million scf/d)
		Power	Industry	Residential and commercial	Transport	Other[a]	Total		
1975	3,007	840	1,322	328	3	767	3,259	678	441
1980	6,712	2,374	2,163	708	6	1,214	6,465	2,263	1,788
1985	10,672	4,540	3,260	1,170	17	1,209	10,196	3,819	3,172
1990	15,091	6,683	3,981	1,821	13	2,246	14,745	5,180	4,480
1991	16,556	7,323	4,164	1,924	24	2,856	16,291	5,696	4,852
1992	17,466	7,649	4,301	2,178	25	2,998	17,151	5,978	5,225
1993	18,354	7,927	4,545	2,383	32	3,163	18,049	6,228	5,601
1994	19,638	8,957	4,785	2,535	33	3,446	19,756	6,868	6,087
1995	20,912	9,551	5,106	2,799	38	3,652	21,145	7,132	6,288
1996	22,824	10,320	5,467	3,171	48	3,921	22,926	8,116	7,268
1997	24,484	11,553	5,530	3,316	61	4,373	24,834	8,667	7,508
1998	25,365	11,981	5,891	3,388	77	4,401	25,738	8,873	7,494
1999	27,157	12,743	6,439	3,661	97	4,727	27,668	9,524	7,783
2000	27,891	13,508	6,976	3,946	125	4,546	29,100	10,149	7,851
2001	28,882	14,629	7,173	4,235	155	4,771	30,963	10,888	7,915
2002	31,072	15,762	7,602	4,450	181	4,649	32,644	11,188	8,596
2003	33,045	17,197	8,094	4,762	207	5,157	35,417	12,449	8,746
2004	34,074	18,131	8,723	5,142	238	5,234	37,468	13,201	9,370
2005	36,831	18,634	9,556	5,564	293	5,599	39,647	13,876	10,335
2010	46,903	24,151	12,235	7,716	551	6,728	51,381	18,143	12,623
2015	55,293	31,023	15,388	11,099	1,238	7,844	66,592	26,981	15,315

Source: FACTS Global Energy (2006).
Note: Data for 1975–2004 are actual, data for 2005 are preliminary, and data for 2010 and 2015 are forecasts.
[a] Includes agricultural use, field use, and non-specified other uses; excludes distribution losses.
[b] Includes imports and exports among countries within the region and to and from other regions.

Appendix Table 4.2. Average annual growth rate of natural-gas production, consumption by economic sector, imports, and exports in the Asia-Pacific region, 1975–2015 (percent)

Year	Production (percent)	Consumption (percent)						Imports (percent)	Exports (percent)
		Power	Industry	Residential and commercial	Transport	Other[a]	Total		
1975–1990	11.4	14.8	7.6	12.1	9.6	7.4	10.6	14.5	16.7
1990–2000	6.3	7.3	5.8	8.0	25.6	7.3	7.0	7.0	5.8
2000–2005	5.7	6.6	6.5	7.1	18.6	4.3	6.4	6.5	5.7
2005–2010	5.0	5.3	5.1	6.8	13.5	3.7	5.3	5.5	4.1
2010–2015	3.3	5.1	4.7	7.5	17.6	3.1	5.3	8.3	3.9
2005–2015	4.1	5.2	4.9	7.1	15.5	3.4	5.3	6.9	4.0

Source: FACTS Global Energy (2006).
Note: Based on actual data for 1975–2000, preliminary data for 2005, and forecasts for 2010 and 2015.
[a] Includes agricultural use, field use, and non-specified other uses; excludes distribution losses.

Appendix Table 4.3. Natural-gas production, consumption by economic sector, imports, and exports in selected countries/economies of the Asia-Pacific region, 2005 (million standard cubic feet per day: scf/d)

Country/economy	Production (million scf/d)	Consumption (million scf/d)						Imports (million scf/d)	Exports (million scf/d)
		Power	Industry	Residential and commercial	Transport	Other[a]	Total		
Australia	4,140	700	1,054	478	40	301	2,573	0	1,567
Bangladesh	1,294	574	555	163	0	2	1,294	0	0
Brunei	1,067	111	0	0	0	74	186	0	881
China	4,885	349	2,144	964	38	1,026	4,521	0	297
Hong Kong SAR[b]	0	282	0	0	0	0	282	297	0
India	3,090	1,357	714	103	125	1,001	3,300	588	0
Indonesia	7,457	531	1,184	325	7	1,707	3,754	0	3,703
Japan	270	5,290	1,058	1,482	0	46	7,877	7,577	0
Malaysia	6,460	2,408	695	11	8	555	3,676	250	3,076
Myanmar	978	106	46	0	0	15	168	0	810
New Zealand	366	157	140	54	1	15	366	0	0
Pakistan	3,620	1,359	1,111	619	62	280	3,431	0	0
Philippines	350	308	0	0	1	0	309	0	0
Republic of Korea	48	1,050	439	1,249	8	28	2,775	2,695	0
Singapore	0	584	44	0	0	2	631	631	0
Taiwan	53	735	88	117	1	32	973	964	0
Thailand	2,245	2,277	232	0	2	515	3,026	874	0
Vietnam	508	452	53	0	0	0	504	0	0
Total Asia-Pacific	36,831	18,634	9,556	5,564	293	5,599	39,647	13,876	10,335

Source: FACTS Global Energy (2006).
Note: Entries might not add up exactly to totals due to rounding.
[a] Includes agricultural use, field use, and non-specified other uses; excludes distribution losses.
[b] Special Administrative Region.

Appendix Table 5.1. Primary commercial energy consumption in China by source, 1980–2015 (thousand barrels of oil equivalent per day: boe/d)

Year	Primary commercial energy consumption (thousand boe/d)					
	Coal	Oil	Natural gas	Hydropower	Nuclear power	Total
1980	6,251	1,781	263	264	—	8,558
1981	6,232	1,681	235	297	—	8,445
1982	6,574	1,668	220	337	—	8,798
1983	6,961	1,706	225	391	—	9,283
1984	7,659	1,750	230	393	—	10,031
1985	8,023	1,856	236	418	—	10,534
1986	8,355	1,964	249	428	—	10,995
1987	8,917	2,096	253	453	—	11,719
1988	9,558	2,231	263	494	—	12,545
1989	9,695	2,327	275	536	—	12,832
1990	10,845	2,207	279	574	—	13,904
1991	10,442	2,419	292	566	—	13,720
1992	10,808	2,639	292	600	—	14,339
1993	11,461	2,922	306	687	7	15,383
1994	12,232	2,902	320	758	67	16,279
1995	13,303	3,149	325	863	58	17,699
1996	13,890	3,440	328	851	65	18,574
1997	13,559	3,819	347	887	65	18,679
1998	13,416	3,750	367	942	64	18,538
1999	13,081	4,089	403	923	68	18,564
2000	13,112	4,428	447	1,007	76	19,070
2001	12,747	4,539	502	1,256	79	19,123
2002	14,144	4,881	534	1,304	114	20,976
2003	17,008	5,397	600	1,284	196	24,485
2004	19,575	6,188	718	1,540	230	28,251
2005	21,646	6,476	870	1,829	240	31,062
2010	26,993	8,623	1,410	2,717	637	40,380
2015	32,672	10,526	2,487	3,882	1,228	50,794

Sources: OECD/IEA (2006); FACTS Global Enegy (2006).
Note: Data for 1980–2004 are actual, data for 2005 are preliminary, and data for 2010 and 2015 are forecasts.

Appendix Table 5.2. Primary commercial energy consumption in India by source, 1980–2015 (thousand barrels of oil equivalent per day: boe/d)

Year	Primary commercial energy consumption (thousand boe/d)					
	Coal	Oil	Natural gas	Hydropower	Nuclear power	Total
1980	1,134	616	25	211	14	1,999
1981	1,277	662	34	224	14	2,211
1982	1,336	688	45	219	9	2,297
1983	1,433	720	52	226	16	2,447
1984	1,532	774	63	244	18	2,631
1985	1,623	832	77	231	23	2,786
1986	1,743	883	106	244	23	2,999
1987	1,885	941	123	215	23	3,186
1988	2,047	1,012	146	262	26	3,493
1989	2,116	1,103	178	281	21	3,698
1990	2,290	1,119	203	324	28	3,964
1991	2,469	1,210	226	329	25	4,259
1992	2,586	1,277	262	316	30	4,472
1993	2,716	1,357	259	319	24	4,676
1994	2,824	1,521	278	374	26	5,023
1995	3,013	1,638	312	329	36	5,327
1996	3,177	1,767	346	312	41	5,644
1997	3,300	1,882	409	338	46	5,975
1998	3,223	1,994	407	376	54	6,054
1999	3,384	2,132	423	365	60	6,364
2000	3,554	2,158	438	337	77	6,564
2001	3,616	2,165	475	334	88	6,678
2002	3,749	2,187	507	290	88	6,820
2003	3,878	2,227	571	341	80	7,097
2004	4,010	2,337	640	380	76	7,444
2005	4,159	2,384	708	441	80	7,772
2010	4,756	2,848	1,159	552	184	9,500
2015	5,294	3,350	1,675	728	266	11,313

Sources: OECD/IEA (2006); FACTS Global Energy (2006).
Note: Data for 1980–2004 are actual, data for 2005 are preliminary, and data for 2010 and 2015 are forecasts.

Appendix Table 5.3. Consumption of petroleum products in India, 1970–2015 (thousand barrels of oil per day: b/d)

Year	Petroleum product consumption (thousand b/d)							
	Liquefied petroleum gas (LPG)	Naphtha	Gasoline	Kerosene/ jet fuel	Diesel	Fuel oil[a]	Other	Total
1970	6	24	36	91	108	89	36	390
1975	11	42	30	85	152	103	29	452
1980	13	50	36	114	232	129	42	616
1981	16	69	38	124	241	131	43	662
1982	18	69	40	133	255	130	43	688
1983	22	63	43	140	272	138	42	720
1984	28	73	48	152	290	143	40	774
1985	37	72	53	162	316	146	45	832
1986	45	74	57	172	336	149	49	883
1987	52	67	64	185	367	154	51	941
1988	60	76	70	197	394	158	57	1,012
1989	69	80	79	209	436	166	63	1,103
1990	76	79	84	215	429	171	65	1,119
1991	82	80	84	212	497	170	85	1,210
1992	91	79	85	216	529	180	98	1,277
1993	96	77	89	219	561	174	141	1,357
1994	114	76	95	248	610	213	166	1,521
1995	127	86	107	258	659	230	172	1,638
1996	136	94	116	269	726	240	186	1,767
1997	148	139	120	275	769	241	190	1,882
1998	166	194	127	298	775	246	189	1,994
1999	190	242	135	300	835	238	192	2,132
2000	220	254	151	301	816	227	188	2,158
2001	233	262	161	293	789	242	185	2,165
2002	260	279	176	277	787	228	181	2,187
2003	288	272	180	275	770	232	210	2,227
2004	333	297	187	256	827	231	206	2,337
2005	359	267	199	279	831	239	210	2,384
2010	484	307	261	332	994	238	232	2,848
2015	634	376	337	388	1,168	222	225	3,350

Source: FACTS Global Energy (2006).
[a] Includes direct use of crude oil for power generation and industrial purposes.

Acronyms, Abbreviations, and Units of Measurement

APEC: Asia-Pacific Economic Cooperation: members are Australia, Brunei, Canada, Chile, China, Hong Kong Special Administrative Region (SAR), Indonesia, Japan, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, the Philippines, the Republic of Korea, Russia, Singapore, Taiwan, Thailand, the United States, and Vietnam
APM: Administered Pricing Mechanism (India)
APSA: ASEAN Petroleum Security Agreement
ASEAN: Association of Southeast Asian Nations: members are Brunei, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Thailand, Singapore, and Vietnam
ASEAN+3: ASEAN members plus China, Japan, and the Republic of Korea
b/d: barrels per day
boe: barrels of oil equivalent
boe/a: barrels of oil equivalent per annum
boe/d: barrels of oil equivalent per day
BPCL: Bharat Petroleum Corporation, Limited (India)
Btu: British thermal unit
C: centigrade
CAA: Commercial Agreement Area (between Malaysia and Vietnam)
CDM: Clean Development Mechanism (provision of the Kyoto Protocol)
CH_4: methane
Chinaoil: Petrochina International Company, Limited
CIF: cost, insurance, and freight
CIL: Coal India, Limited
CITIC: China International Trust and Investment Company
CNG: compressed natural gas
CNOOC: China National Offshore Oil Corporation (CNOOC Ltd. is its listed subsidiary)
CNPC: China National Petroleum Corporation (PetroChina is its listed subsidiary)
CO: carbon monoxide
CO_2: carbon dioxide
DMCC: Dubai Metals and Commodities Centre
DME: Dubai Mercantile Exchange
EIA: Energy Information Administration (United States Department of Energy)
EPA: Environmental Protection Agency (United States)
F: Fahrenheit
FERC: Federal Energy Regulatory Commission (United States)
FIPB: Foreign Investment Promotion Board (India)
FOB: free on board
FPC: Formosa Petrochemical Corporation (Taiwan)

GAIL: Gas Authority of India, Limited
GDP: Gross Domestic Product
HPCL: Hindustan Petroleum Corporation, Limited (India)
IBP: formerly the Indo-Burma Petroleum Company, Limited (India)
IEA: International Energy Agency of the Organization for Economic Cooperation and Development (OECD)
IMF: International Monetary Fund
IOC: Indian Oil Corporation
IPCC: Intergovernmental Panel on Climate Change
IPE: International Petroleum Exchange (London)
JDA: Joint Development Area (between Thailand and Malaysia)
JOGMEC: Japan Oil, Gas, and Metals National Corporation
km: kilometer
KNOC: Korea National Oil Corporation (Republic of Korea)
KOGAS: Korea Gas Corporation (Republic of Korea)
KW: kilowatt (1 thousand watts)
LNG: liquefied natural gas
LPG: liquefied petroleum gas
m^3: cubic meter
mg/dl: milligrams per deciliter
MLNG: Malaysia Liquefied Natural Gas Tiga
MW: megawatt (1 million watts)
N_2O: nitrous oxide
NAAQS: National Ambient Air Quality Standards (United States Environmental Protection Agency)
NDRC: National Development and Reform Commission (China)
NGL: natural-gas liquid
NO_2: nitrogen dioxide
NO_x: nitrogen oxides
NTPC: National Thermal Power Corporation (India)
NWS: Northwest Shelf Consortium (Australia)
NYMEX: New York Mercantile Exchange (United States)
O_3: tropospheric ozone
OECD: Organization for Economic Cooperation and Development: members are Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Republic of Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States
OECD/IEA: Organization for Economic Cooperation and Development/International Energy Agency
ONGC: Oil and Natural Gas Corporation (India)
OPEC: Organization of the Petroleum Exporting Countries: members are Algeria, Angola, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates (Abu Dhabi and Dubai), and Venezuela
OVL: Oil and Natural Gas Corporation (ONGC) Videsh, Limited (India)

PEC: primary energy consumption
PGU: Peninsular Gas Utilization project (Malaysia)
pH: a measure of the activity of hydrogen ions in a solution, indicating its acidity or alkalinity
PM_{10}: particulate matter
ppm: parts per million
PPP: purchasing power parity
PRB: Population Reference Bureau
PV: photovoltaic
RIL: Reliance Industries, Limited (India)
R/P: Reserve-to-production ratio, calculated as the reserves remaining at the end of a year divided by production in that year, resulting in the number of years that the remaining reserves will last if production continues at the same level
SAR: Special Administrative Region (Hong Kong)
scf: standard cubic feet
scf/d: standard cubic feet per day
SDPC: formerly State Development Planning Commission (China)
Sinopec: China Petrochemical Corporation (Sinopec Corp is its listed subsidiary)
SO_2: sulfur dioxide
SPV: Special Purpose Vehicle (India)
t: tonne or metric ton, equivalent to 1,000 kilograms or 2,205 pounds
t/a: tonnes per annum
TAGP: Trans-ASEAN Gas Pipeline
TEPCO: Tokyo Electric Power Company (Japan)
TOCOM: Tokyo Commodity Exchange (Japan)
TWh: terawatt (1 trillion watts) hours
UNEP: United Nations Environment Program
UNFCCC: United Nations Framework Convention on Climate Change
Unipec: United Petroleum and Chemicals Company, Limited (China)
U.S.: United States
WHO: World Health Organization
WMO: World Meteorological Organization
WTI: West Texas Intermediate crude oil
WTO: World Trade Organization

References

Foreword

BP. 2006. *BP statistical review of world energy 2006.* London: BP.

EIA (Energy Information Administration). 2005. *American energy outlook 2005: With projections to 2025.* Washington, D.C.: U.S. Department of Energy.

———. 2006. *American energy outlook 2006: With projections to 2030.* Washington, D.C.: U.S. Department of Energy.

FACTS Global Energy. 2006. *FACTS global energy database.* Honolulu: FACTS Global Energy.

OECD/IEA (Organization for Economic Cooperation and Development/International Energy Agency). 2005. *World energy outlook 2005: Middle East and North Africa insights.* Paris: OECD/IEA.

———. 2006. *Monthly oil market report.* Various issues. Paris: OECD/IEA.

Chapter One: The Asia-Pacific Energy Dilemma

BP. 2006. *BP statistical review of world energy 2006.* London: BP.

EIA (Energy Information Administration). 2006. *International energy outlook.* Washington, D.C.: U.S. Department of Energy.

FACTS Global Energy. 2006. *FACTS global energy database.* Honolulu: FACTS Global Energy.

IMF (International Monetary Fund). 2005. *World economic outlook: Building institutions.* Washington, D.C.: IMF.

OECD/IEA (Organization for Economic Cooperation and Development/International Energy Agency). 2006. *OECD/IEA energy database.* Paris: OECD/IEA.

Oil & Gas Journal. 2005. Worldwide look at reserves and production. *Oil & Gas Journal* (19 December) 103(47).

Park, Cyn-Young. 2004. *Higher oil prices: Asian perspectives and implications for 2004–2005.* Policy Brief No. 28. Manila: Economics and Research Department, Asian Development Bank.

PRB (Population Reference Bureau). 2005. *2005 world population data sheet.* Washington, D.C.: PRB.

Chapter Two: The Environmental Context of Energy

Aldy, Joseph E., John Ashton, Richard Baron, Daniel Bodansky, Steve Charnovitz, Elliot Diringer, Thomas C. Heller, Jonathan Pershing, P. R. Shukla, Laurence Tubiana, Fernando Tudela, and Xueman Wang. 2003. *Beyond Kyoto: Advancing the international effort against climate change.* Washington, D.C.: Pew Center for Global Climate Change.

Arnold, Wayne. 2005. Malaysia, blanketed in noxious haze, declares emergency. *New York Times.* 11 August.

Asian Development Bank. 1999. *Sustainable cities: Environmental challenges in the 21st century.* Manila: Environment Division, Asian Development Bank.

BP. 2005. *BP statistical review of world energy: June 2005.* London: BP.

———. 2006. *BP statistical review of world energy 2006.* London: BP.

CECL (Consolidated Energy Consultants, Ltd.). 2006. *WindPower India.* 66 (15 January). Web site at http://www.windpowerindia.com/newsdetailer.html#bkmark1. Accessed 12 March 2006.

Dasgupta, Susmita, Mainul Huq, M. Khaliquzzaman, Kiran Pandey, and David Wheeler. 2004. *Who suffers from indoor air pollution? Evidence from Bangladesh.* Policy Research Working Paper Series No. 3428. Washington, D.C.: World Bank.

Economy, Elizabeth. 2004. Don't break the engagement. *Foreign Affairs* 83(3): 96–109.

EIA (United States Energy Information Administration). 2004. *Figure ES 2. U.S. net generation by energy source, 2003.* Washington, D.C.: U.S. Department of Energy. Web site at http://www.eia.doe.gov/cneaf/electricity/epa/figes2.html. Accessed 12 July 2005.

EPA (United States Environmental Protection Agency). 2005. *National Ambient Air Quality Standards (NAAQS).* Web site at http://www.epa.gov/air/criteria.html. Accessed 4 March 2005.

FACTS Global Energy. 2005. *FACTS energy database.* Honolulu: FACTS Global Energy.

He, Kebin, Huo Hong, and Zhang Qiang. 2002. Urban air pollution in China. *Annual Review of Energy and the Environment* 27:397–431.

Huizenga, Cornie, Gary Haq, and Dieter Schwela. 2003. *Benchmarking air quality management in Asian cities.* Paper presented at the Workshop on Better Air Quality Management in Asian Cities, Manila, Philippines, 17–19 December.

JAIF (Japan Atomic Industrial Forum). 2005. *Nuclear power plants in the world.* Web site at http://www.jaif.org.jp/english/news/2005/0620-doukou.html. Accessed 26 May 2007.

Jeon, Tae-Bong. 2001. Air quality management policy in Korea. In Gary Haq, Wha-Jin Han, and Christine Kim, eds. *Urban air pollution management and practice in major and mega cities of Asia.* Seoul: Korea Environment Institute.

Ku, Jean, Debra Lew, and Shenhong Ma. 2003. Sending electricity to townships. *Renewable Energy World* (September–October): 56–67.

Li, Junfeng, Li Shi, and Lingjuan Ma. 2006. An overview of domestic and international renewable energy. *International petroleum economics* (in Chinese) 14(2): 35–37.

Martinot, Eric, Akansha Chaurey, Debra Lew, Jose Roberto Moreira, and Njeri Wamukonya. 2002. Renewable energy markets in developing countries. *Annual Review of Energy and the Environment* 27:309–48.

OECD/IEA (Organization for Economic Cooperation and Development/International Energy Agency). 2005a. *Energy statistics and balances of OECD countries.* Paris: OECD/IEA.

———. 2005b. *Energy statistics and balances of non-OECD countries.* Paris: OECD/IEA.

REN21 (Renewable Energy Policy Network for the 21st Century). 2006. *Renewables global status report 2006 update.* (Lead author: Eric Martinot.) Paris: Renewable Energy Policy Network for the 21st Century.

Siddiqi, Toufiq A. 2000. The Asian financial crisis—is it good for the global environment? *Global Environmental Change* 10:1–7.

U.S. (United States) Department of State. 2005. *Vision statement of Australia, China, India, Japan, the Republic of Korea, and the United States for a new Asia-Pacific Partnership on Clean Development and Climate.* Web site at http://www.state.gov/g/oes/rls/fs/50335.htm. Accessed 30 January 2006.

Victor, David G. 2004. *Climate change: Debating America's policy options.* New York: Council on Foreign Relations.

Walsh, Bryan. 2004. Indoor pollution: So are you safe inside? No chance. *TIME Asia Magazine* 164 (13 December). Web site at http://www.time.com/time/asia/magazine.html. Accessed 20 June 2005.

Wangwongwatana, Supat. 2002. *Air quality management in Bangkok: Trends and challenges.* Paper presented at the Conference on Better Air Quality in Asian and Pacific Cities, Hong Kong, 16–18 December.

WHO (World Health Organization). 2000. *Air quality guidelines for Europe.* Second Edition. Geneva: WHO.

WMO and UNEP (World Meteorological Organization and United Nations Environment Program). 2001. *Climate change 2001: The scientific basis: Summary for policymakers and technical summary of the Working Group I report.* Geneva: Intergovernmental Panel on Climate Change (IPCC) Secretariat.

World Bank. 1992. *World development report 1992: Development and the environment.* New York: Oxford University Press.

———. 2004. *World development indicators, 2004.* Washington, D.C.: World Bank.

World Commission on Dams. 2000. *Dams and development: A new framework for decision-making.* London: Earthscan.

Zhang, ZhongXiang. 2003. Why did the energy intensity fall in China's industrial sector in the 1990s? The relative importance of structural change and intensity change. *Energy Economics* 25:625–38.

Chapter Three: Oil

BP. 2006. *Statistical review of world energy 2006.* London: BP.

EIA (Energy Information Administration). 2006. *Country analysis briefs: Russia.* Washington, D.C.: U.S. Department of Energy.

FACTS Global Energy. 2006. *FACTS global energy database.* Honolulu: FACTS Global Energy.

Milov, Vladimir. 2005. The Russian Pacific oil pipeline: More questions than answers. *The Northeast Asia Energy Focus* 2(3): 10–14.

Wu, Kang. 2002. Asia-Pacific oil dependence, imports to grow. *Oil & Gas Journal* 100(15): 20–23.

Chapter Four: Natural Gas

BP. 2006. *BP statistical review of world energy 2006.* London: BP.

EIA (Energy Information Administration). 2006. *American energy outlook 2006: With projections to 2030.* DOE/EIA-0383 (2006). Washington, D.C.: U.S. Department of Energy.

FACTS Global Energy. 2006. *FACTS global energy database.* Honolulu: FACTS Global Energy.

Chapter Five: China and India

BP. 2006. *BP statistical review of world energy 2006.* London: BP.

China, General Administration of Customs. 2006. *Database.* Beijing: General Administration of Customs.

FACTS Global Energy. 2006. *FACTS global energy database.* Honolulu: FACTS Global Energy.

Fesharaki, Fereidun, and Takuya Murata. 2006. *India's nuclear power update and energy demand outlook.* Energy Advisory No. 317. Honolulu: FACTS Global Energy.

Gao, Shixian. 2003. China. In *Securing energy—China's policy and its wider strategic implications.* Berlin: German Council on Foreign Relations.

OECD/IEA (Organization for Economic Cooperation and Development/International Energy Agency). 2006. *OECD/IEA energy database.* Paris: OECD/IEA.

PRB (Population Reference Bureau). 2005. *2005 World population data sheet.* Washington, D.C.: Population Reference Bureau.

Wu, Kang. 2002. Oil demand and supply structures and market developments in China: Current situation and future prospects. In *Proceedings of the Cross-Straits Energy Forum.* Taipei: Energy Commission, Ministry of Economic Affairs, and Taiwan Research Institute.

Chapter Six: Policy Priorities

EIA (Energy Information Administration). 2004. *India: Environmental issues.* Country Analysis Briefs. Washington, D.C.: U.S. Department of Energy. Web site at http://www.eia.doe.gov/emeu/cabs/indiaenv.html. Accessed 26 July 2006.

Fesharaki, Fereidun, and Jeffrey G. Brown. 2003. Asia's new dynamics of energy demand/supply in the twenty-first century. In Y.H. Kim and M. Uchida, eds. *The new wave in Northeast Asia: Energy and electricity business in the 21st century.* Tokyo: Keio University Press.

Hai, Song. 2005. Notes on the Special Program for Mid- to Long-Term Energy Conservation. *Energy of China* (in Chinese) 2:17–21.

Li, Junfeng, Li Shi, and Lingjuan Ma. 2006. An overview of domestic and international renewable energy. *International Petroleum Economics* (in Chinese) 14(2): 35–37.

OECD/IEA (Organization for Economic Cooperation and Development/International Energy Agency). 2004. *World energy outlook.* Paris: OECD/IEA.

_______. 2005. *Resources to reserves: Oil and gas technologies for the energy markets of the future.* Paris: OECD/IEA.

Salameh, Mamdouh G. 2004. *Over a barrel.* Beirut: Raidy Printing Press.

Appendix: Forecasting Methodology

Medlock, Kenneth B., III, and Ronald Soligo. 2001. Economic development and end-use energy demand. *The Energy Journal* 22(2): 77–105.

OECD/IEA (Organization for Economic Cooperation and Development/International Energy Agency). 2004a. *Energy statistics and balances of OECD countries.* Paris: OECD/IEA.

_______. 2004b. *Energy statistics and balances of non-OECD countries.* Paris: OECD/IEA.

Summers, Robert, and Alan Heston. 1995. *Penn world table.* Mark 5.6a. Philadelphia: Center for International Comparisons, University of Pennsylvania.

United Nations. 2002. *World population prospects: The 2002 revision.* New York: Population Division, Department of Economic and Social Affairs, United Nations.

World Bank. 2003. *Global development finance 2003: Striving for stability in development finance.* Washington, D.C.: World Bank.

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BELOW

Time-lapse photo taken during rush hour in a commuter train station, Mumbai, India. By 2025, India will have surpassed China to become the most populous nation in the world. © Raghu Rai/ Magnum Photos

FRONT COVER

Shipyard worker repairs an oil tanker at Qili Port, Zhejiang Province, China. In 1993, China became a net oil importer, and imports of crude oil and petroleum products have risen steadily ever since. © Edward Burtynsky, courtesy Robert Koch Gallery, San Francisco, and Charles Cowles Gallery, New York