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Number 23

Energy Demand in the Developing Countries

Prospects for the Future

Mudassar Imran
Philip Barnes

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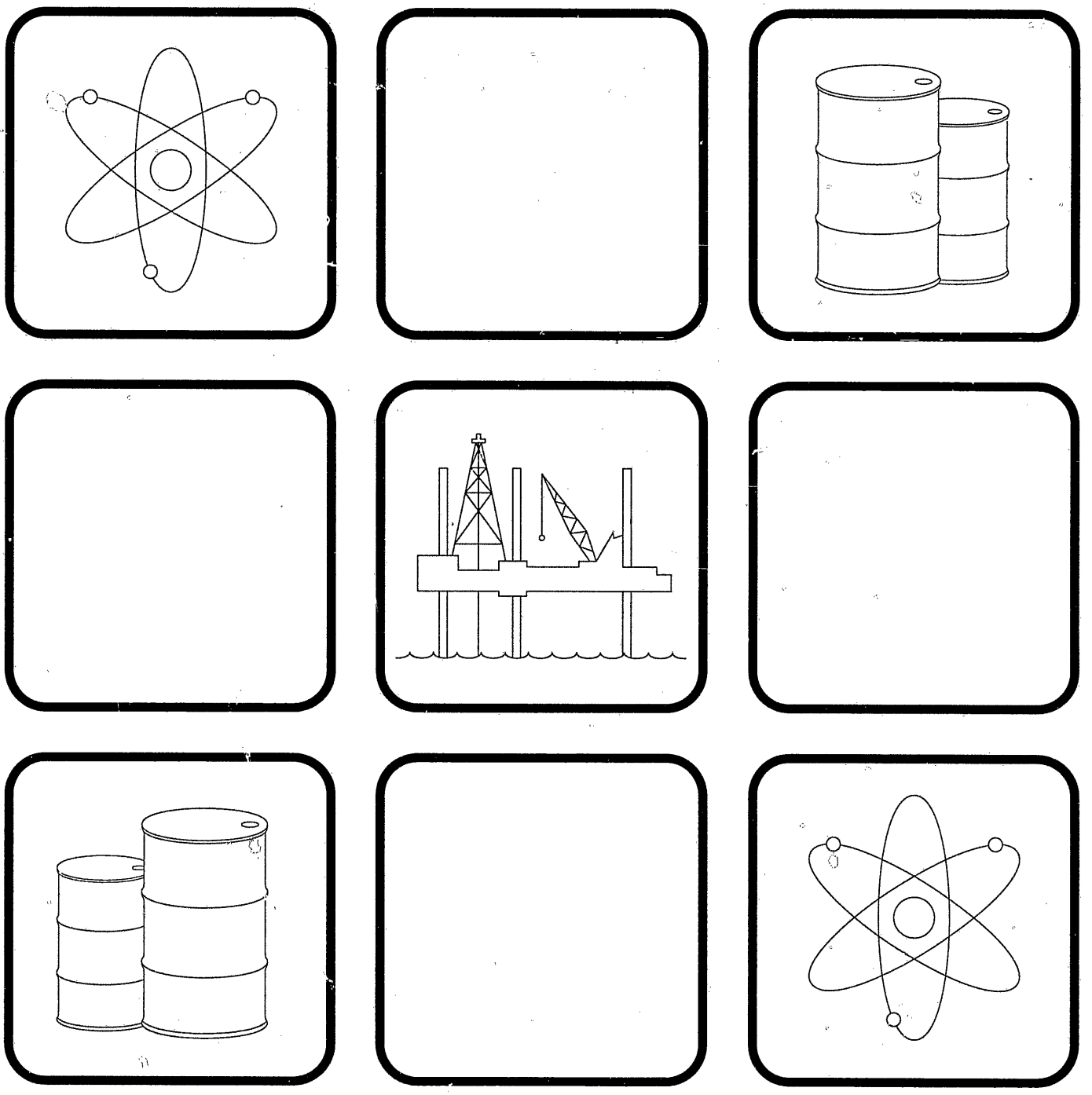

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ABSTRACT

In recent years, energy consumption has increased rapidly in the developing countries. Their share in global energy consumption (outside of the USSR and Eastern Europe) has increased from 20% in 1970 to 33% in 1988. It is anticipated that these energy consumption trends will continue. Given their growing role in the global energy markets, the main motivation of this study was to highlight the key factors that have contributed to the historical increases in energy consumption in the developing countries as well as to project the changes likely to occur in the future. The scenarios for the future take into account the changing relationships between economic growth and energy consumption, structural changes, and the potential for fuel substitution. The evaluation of these elements has been based on sectoral analysis of demand for various fuels in the key sectors and the developing patterns in and limitations on fuel supply. The outlook for the future is reached by using analytical techniques as well as econometric model-based simulations. The study covers eight major developing countries representing about one-half of total energy consumption in the developing countries. Because of their diversity and size, the conclusions reached about these countries can reasonably be extrapolated to developing countries as a whole.

The results of the study indicate that increased levels of motor vehicle use and urbanization are the main factors contributing to increases in energy consumption in the developing countries. These factors, as well as rising incomes and shifts away from the use of traditional fuels, will continue to support increases in commercial energy use over the long term. As a result of fuel substitution, the pattern of fuel use will change during the 1990s. Gas is likely to become a more popular fuel, encouraged by changes in pricing and exploration policies and the development of major gas distribution projects. Aided later in the 1990s by environmental concerns, its share of commercial primary energy could triple by 2010. The share of coal in total primary energy is expected to fall significantly. However, in volumetric terms its use is projected to double, largely through increased use for electricity generation--particularly in China and India. Hydro use is also expected to more than double, with substantial growth taking place in China and India. Oil consumption seems likely to more than double by 2010, even under optimistic assumptions on conservation and substitution--largely due to increasing motorization and switching out of traditional fuels in the residential sector. Under the business-as-usual scenario, oil consumption of the five oil-importing countries will triple by 2010. The oil import requirements of this group could reach 65% and 88% of total oil needs in 2000 and 2010, respectively.

It is estimated that the total energy savings, due to improved efficiency and substitution, will be of the order of 23% of total energy use and 33% of oil use by the year 2010. The potential for savings is largest in the residential and commercial sectors in China and in the industrial sector in the other countries.

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SUMMARY

This paper represents a distillation of the views gleaned from an in-depth study of energy demand in eight developing countries (Brazil, China, India, Indonesia, Malaysia, Pakistan, the Philippines and Thailand). In terms of per capita income, these countries range from India and Pakistan, with incomes well under $500 per capita, to Malaysia and Brazil in the upper bracket of the middle-income developing countries. They also have a wide variety of energy use and policies; from major reliance on coal and traditional fuels to sophisticated gas systems and high levels of electricity penetration. In total the eight countries account for over 50% of total energy and 35% of oil consumed in the developing countries.

In contrast to the OECD countries, the developing countries in aggregate have shown a steady increase in the intensity of their commercial energy use through the late 1970s and 1980s. This has also generally been the case with the eight countries studied, although in three of them intensities leveled off in the 1980s. There are distinct differences between energy intensities in the eight countries, however, related to the structure of their economies, their fuel mix, activity levels, climate, pricing policy, etc. and these differences are brought out in the individual chapters.

The strong expansion of motor vehicle use has resulted in fuel for transport needs becoming the largest single outlet for oil products in all the eight countries. The level of car ownership tends to be higher than in lower-income OECD countries when they were at similar per capita income levels. Apart from Brazil, motorcycles are used extensively and their rapid growth in the vehicle population in recent years has caused fuel consumption per vehicle to fall rapidly. Cars are, however, generally less efficient than those in the OECD. Congestion and local pollution will place limitations on vehicle use in some of the major cities such as Jakarta. However, we expect the desire for personal mobility and increased trade in goods to continue to be reflected in rapid increases in road transport. A five-fold increase in vehicle population over the next 20 years is feasible. The impact of this increase on fuel consumption will be partly offset by the globalization of car manufacturing and the resulting faster international transfer of new vehicle technology which will mean that car and truck fuel efficiencies should improve faster than in the past. Air travel will continue to expand at a faster rate than per capita income as incomes grow and business and pleasure needs require faster travel; but the introduction of more fuel-efficient aircraft will moderate the growth in aviation fuel use. In sum, we expect that transport in total will slightly increase its share of final energy demand over the next 20 years or so.

The consumption of energy for lighting, cooking and for appliances by households and the service industry has shown significant changes in recent years. Growth in household incomes and in urbanization has been accompanied by a change in the fuel mix to more efficient fuels; partly as a result, energy consumption per household appears to have stagnated in some countries. The continued spread of urbanization and rising incomes will continue to reduce the share of traditional fuels used by households. Indeed, the historical transition from traditional fuels to kerosene and to LPG and

electricity will accelerate; perhaps the kerosene step will be by-passed in some urban areas. We have assumed that the intense local pollution in China, caused by the present reliance on coal for space heating, will not be seriously tackled until the late 1990s. Nonetheless, rural electrification schemes will be completed in China and there will be greater use of natural gas by households as the projects currently under way in a number of developing countries are completed. As household incomes rise an increasing share of energy is used for other than basic cooking and lighting--largely for appliances which, in the main, use electricity. Probably for this reason electricity use has been growing faster than any other source of energy for household and service industry use in all the countries reviewed. This has played a major part in keeping growth in total energy use low. We expect that the continued substitution of more efficient fuels for household use and the expansion of the service industry, largely based on electricity, will keep the intensity of energy use low. Thus, energy consumption in this sector will continue to grow with the inexorable growth of population and urbanization, but at a lower rate than per capita income. Thus its share of final market demand will fall.

Industrial use accounts for the largest share of final energy consumption in all the countries reviewed, except for Malaysia and Thailand. In almost all the countries reviewed, the current efficiency of energy use by industries is low by international standards. Industrial policies in a number of the countries have reflected a significant shift in the past decade, with some moving to lighter, less energy-intensive industries; whereas others are still in the basic stage of building up heavy industries. We expect the growth of heavy industry to continue through the 1990s in the lower-income countries, with expansion based on the latest technologies. Incorporation of new technology, together with the greater use of gas and electricity, will improve industry energy efficiency significantly and at a faster rate than in the past. In the more advanced countries of the group the emphasis on low-cost, efficient, export and higher-technology industries will also change industry structure in favor of less energy-intensive manufacturing. This process will be aided by an increasing role for market forces in line with the change in policies in a number of countries that have occurred since the early 1980s.

Electricity consumption generally grows much faster than income as countries develop. Its generation represents the fastest growing call for energy and the largest single market in most of the countries reviewed. Brazil has the highest electricity consumption per capita, reflecting its higher income and degree of urbanization, whilst Indonesia is apparently at the lowest level of use. It is envisaged that there will be endeavors to reduce the present high level of electricity losses in these countries and the expansion and modernization of grid systems generally will help to moderate the need for new generating capacity. Nonetheless, electricity generation will represent the largest single need for energy in all eight countries by the late 1990s. In the medium term, some countries will have recourse to additional use of oil-fired capacity. The availability of coal and hydro should lead to their making up the bulk of incremental capacity in China and India (within this time frame we do not expect that there will be a significant impact from international initiatives on global warming on the growth in coal consumption in these two countries). Elsewhere, gas will tend to be used--as it becomes available--because of its low initial costs and

other benefits, including cleanliness. A major problem that all of the countries will face is that of capital scarcity, which may be eased to some extent by the encouragement of private initiatives and realistic pricing policies. The very substantial expansion of grid systems also poses serious management and technical problems.

As a result of continuing structural change and substitution, the pattern of fuel use will change during the 1990s. All the countries reviewed, except perhaps the Philippines, have gas resources. Gas is becoming a favored fuel, encouraged by changes in pricing and exploration policies and the development of major gas distribution projects. If this continues, perhaps aided later in the 1990s by environmental concerns, we expect its share of commercial primary energy will treble by 2010.

All countries will show some increase in coal use, mainly for electricity generation, although outside of India and China it is expected to be very modest.

Hydro construction will be adversely affected by capital shortages and some environmental problems but there is substantial untapped potential in all the countries. We expect use to more than double by 2010.

In making the assessment of each country's future demand and supply of energy, we have developed a scenario that is based on the World Bank's forecasts of economic growth. The scenario also takes into account the changing relationships between economic growth and energy demand, structural change, and the potential for fuel substitution that we observe from our eight country studies. The evaluation of these elements has been based on careful sectoral analysis of demand for energy in the key markets and of the developing pattern and supply limitations on fuel use within the context of investment plans and energy policies in the various countries. As well as this basic ground-up analysis we have also run the oil demand models constructed for each country. The purpose of this twin approach was to illustrate the higher energy consumption that is likely to occur if the practices of the 1980s and 1990s are allowed to continue into the next century. The impact of the changing relationships is illustrated by the differences between the results from the analytical projections and those from the models when both sets of projections are based on identical economic and demographic assumptions. A significant level of consistency is shown between the two methods in the short to medium term but there is considerable divergence from the late 1990s onwards.

The need to preserve indigenous oil for export in the three oil-exporting countries and to guard against balance of payments problems in the importers is likely to mean heightened continuation of efforts to reduce oil consumption. However, even under optimistic assumptions on conservation and substitution, oil consumption seems likely to more than double in these countries by the year 2010. Alternatively, however, under the assumption of the continuation of the oil consumption trends of the 1980s and 1990s, oil consumption would triple by 2010 and the oil import requirements in the five oil-importing countries would reach around 88% of the total oil needs by 2010 (compared with 37% in 1988). Given their strong growth in oil consumption and their rapidly-depleting oil reserves, the three oil-exporting developing countries are likely to become oil importers by 2010. The fastest growth will

be in transport fuels, with some additional growth in fuel oil and diesel for electricity generation in the medium term.

The results from the analytical projections indicate that energy intensity will continue to increase through the early 1990s, particularly in some of the poorer countries--since these countries will still be in the earlier stages of developing their industrial base. However, in general, intensities will level off and begin to fall during the 1990s. This is in marked contrast with the generally increasing energy intensities of the past. Clearly, change may also occur faster than we have assumed--particularly in the first decade of the next century as a result of local or global environmental initiatives or, as yet, unknown technological innovations. It is estimated from the sectoral analysis of demand that the potential for total energy savings is some 15 mb/doe for the eight countries over the next 20 years. This represents of the order of 23% of total energy use in 2010. For oil, the savings indicated are about 6 mb/doe or 32% of oil use in 2010. The potential for energy savings is the largest in the residential and commercial sectors (42%) followed by the transport sector (23%) and the industry sector (21%). However, if we exclude China, the energy savings potential seems largest in the industrial sector, representing in the order of 26% of total energy use in the seven countries.

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I. INTRODUCTION

In recent years, the role of developing countries has grown rapidly in the global energy market. The share of developing countries in global energy consumption [outside the centrally planned economies (CPEs)] increased rapidly from 20% in 1970 to 33% in 1988. This was mainly the result of lower economic growth and oil use in the industrial countries during the late 1970s and early 1980s in response to higher oil prices. However, despite the increase in developing countries' share, their rate of growth in energy use has declined considerably over the last two decades--it was 7.5% p.a. between 1961 and 1970 but only 5.5% in the period from 1970 to 1988. The sharply-higher energy prices and a slowdown in economic growth were also the two main factors that contributed to their slower energy consumption growth.

Despite the slowdown in the growth of total energy consumption, the average energy intensity in developing countries has, with occasional fluctuations, continued a steady upwards trend--rising from around 3 barrels of oil equivalent (boe) per thousand dollars of output (in constant 1980 dollars) to nearly 4 boe in the late-1980s. This increase is in sharp contrast to the OECD countries, where energy intensity has declined from around 4.2 boe per million dollars of output in 1970 to under 3.2 boe in 1988. However, the movement in energy intensities has been significantly dissimilar across developing country regions. Energy intensities in most oil-exporting regions have generally remained below the average, due largely to the disproportionately high contribution of the oil industry to GDP; energy intensity in the oil-importing countries has been relatively high. Although the increase in energy intensities in the developing countries is partly due to less efficient energy use, other contributing factors to this increase are the energy-intensive structural shifts as reflected in the spread of urbanization and increased levels of motorization in line with rising per capita incomes and population. The increase in energy-intensive, heavy industrial plants (such as steel and chemicals), the shift away from non-commercial energy sources to commercial fuels, and the demand for higher comfort levels leading to increases in the use of electric appliances have also contributed to the rapid growth in energy use. All these factors together have resulted in the faster growth of oil and energy consumption in the developing countries compared to the industrial countries.

Since 1986, following the collapse in international oil prices, global oil/energy demand has increased significantly; halting the declining trends in oil and energy intensities in the OECD countries and strengthening the momentum of energy consumption growth in developing countries (almost double that of the OECD). Despite the increasing growth trends in oil and energy consumption in the industrial countries over the past three years, the general expectation is that their growth in energy and oil use is likely to moderate over the medium to long term. This expectation is reinforced by the repeated affirmation by the industrial countries to improve energy efficiency; latterly given more emphasis by environmental concerns accentuated by the threat of global warming, and heightened conservation efforts to reduce dependence on imported oil. The existence and continued development of technologies that allow greater flexibility between factors of production generally and between energy sources in particular is also of significance.

It is anticipated, therefore, that around two-thirds of the incremental energy demand in countries other than what have been called the centrally planned economies is likely to occur in the developing countries, with their share rising sharply to over 40% by the turn of the century. Although energy consumption is expected to grow in all developing country regions, consumption increases are envisaged to be most rapid in the South Asian and Pacific Rim regions.

Given the increasing role of the developing countries in the global energy market, therefore, a deeper understanding of their energy demand and its prospects is essential for a better grasp of the changes likely in the global market. Of particular importance is whether growth and intensity of energy use in the developing countries will continue at the past high rates for a substantial period. Towards this end, a group of developing countries was selected for study (Brazil, China, India, Indonesia, Malaysia, Pakistan, the Philippines and Thailand). The geographical concentration of the countries is in the fast-growing South Asian and Pacific Rim regions. Within the group of countries selected there is a diversity to reflect different per capita income levels as well as different energy-resource endowments. The analytical techniques followed were detailed sector-level studies of historical trends, econometric model-based simulations of historical data, as well as scenario analysis and model-based projections to evaluate likely future developments. Because of their diversity and their size, the conclusions reached about the eight countries studied can reasonably be extrapolated to developing countries as a whole.

II. ENERGY CONSUMPTION PATTERNS

The eight countries studied account for some 53% of total energy and 35% of oil consumption in the developing countries. However, it is only rarely that one country can be taken as typical of another and the countries reviewed are no exception in their disparity. China, Indonesia, and Malaysia are major exporters of hydrocarbons, whilst the other five are net importers. China is the world's largest coal producer, Brazil obtains over 25% of its fuel for road transport from sugarcane, Pakistan has the most extensive natural gas grid in the developing world, and there are many other examples of uniqueness. In terms of development, the countries range from an annual income per head of around US$300 in India to over US$2,000 in Malaysia and Brazil. Populations range from 17 million in Malaysia to over a billion in China; while the degree of urbanization ranges from 18% in Thailand to 73% in Brazil. Nonetheless, there are similarities from which clues can be obtained about the future; particularly as to the extent to which developing countries will follow the same pattern of energy development as other developing countries or OECD countries have in the past.

A. General Developments

All the countries reviewed pursue, with varying degrees of intent and success, energy policies which attempt to restrain the amount of oil consumed and increase the use of indigenous alternatives. There is a high level of state control and interest in all aspects of energy supply and demand, although in recent years more economic rationality and flexibility has been shown in encouraging indigenous supply sources and optimizing energy use.

Traditional fuels still play a significant role in each country's energy economy but in all countries its share has been falling with the fast growth in commercial energy consumption. During the 1970s, oil consumption grew roughly in line with total commercial energy, with the fastest growth occurring in the households sector. The sharp price increase of 1979 and the recession that followed, together with the implementation of more realistic internal pricing and diversification policies, caused oil demand growth to slow and road transport has become the fastest-growing final market.

In all countries, except China and Thailand, electricity generation is the largest and fastest-growing market for energy. Industry tends to take the next biggest share in the earlier stages of development but transport takes over once a basic level of industrialization and income has been reached (Figures 1A and 1B).

The intensity of commercial energy use is related roughly to income, with the development of basic industrialization and urbanization leading to a peak in intensity; which is eventually followed by a decline as economies mature. Brazil and Malaysia are probably nearing their peak intensities but the others are on the upward curve. There is, however, little in the way of a clear trend in the level of energy intensity. Indonesia and the Philippines are both at the same level. Malaysia, with roughly the same per capita income

Fig.1A Commercial Energy Consumption by Markets, ('000 b/doe), 1988.

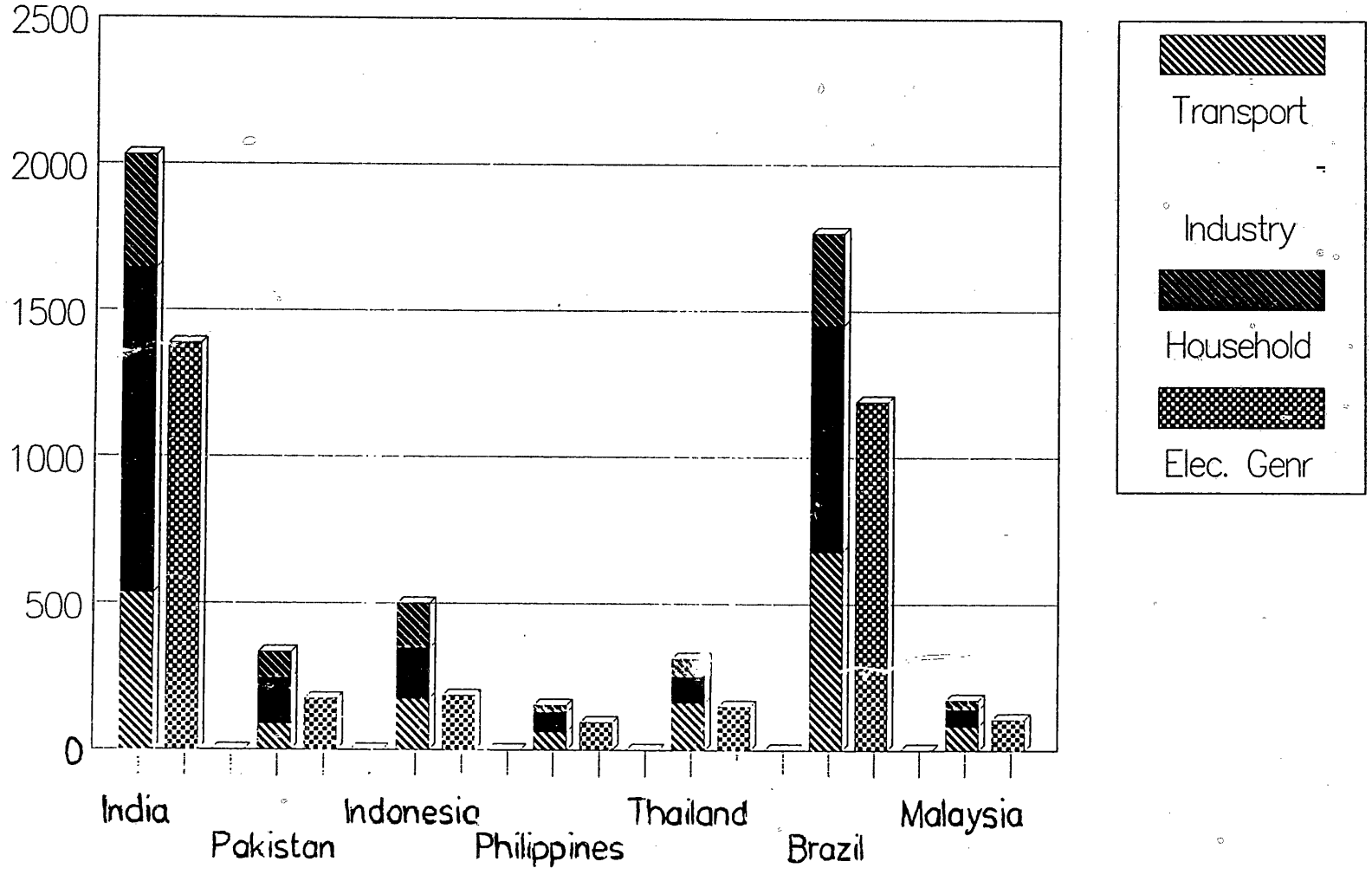
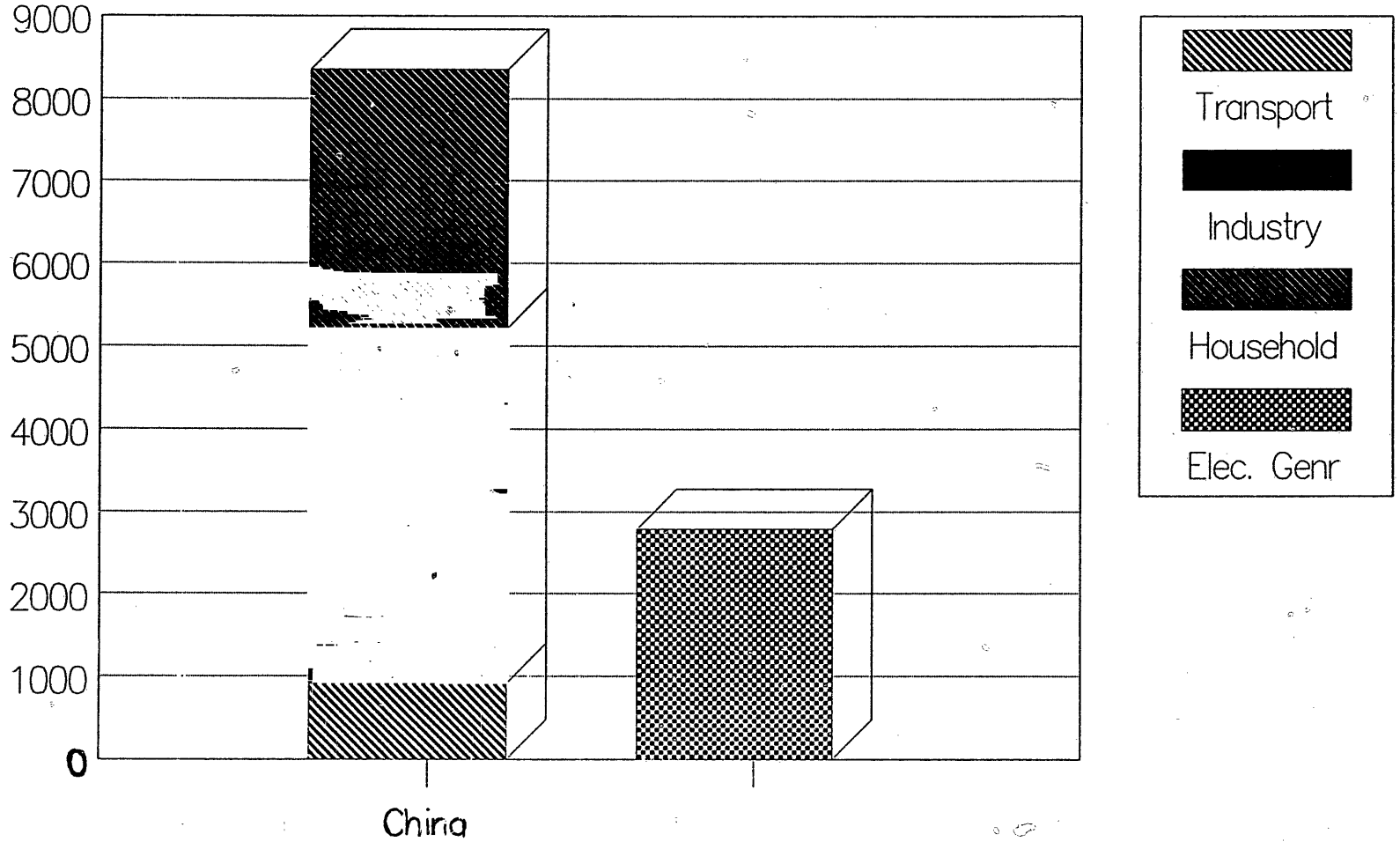


Fig.1B Commercial Energy Consumption

by Markets ('000 b/doe), 1988



as Brazil has an energy intensity 35% higher while India, with the lowest per capita income, has the highest commercial energy intensity. Clearly, these disparities are related to the structure of the economies, their activity levels, geography, climate, and fuel efficiency.

Commercial energy intensities increased steadily in most developing countries through the 1970s; of the eight countries reviewed the Philippines is the only exception (Table 1). India, Indonesia, Pakistan, and Thailand continued to increase intensities during the 1980s whereas in the other four countries, intensities leveled off or even fell. The intensity of energy consumption in final markets tends to follow roughly the same pattern as primary energy intensity but with lags and distortions largely due to differences in the role of electricity.

The reasons for these past changes are complex and it is only by examining the individual elements in the main markets that one can hope to arrive at a sound basis for judging future developments.

B. Motorization: The Driving Force for Future Oil Demand

The seemingly unstoppable need for mobility has resulted in transport becoming the largest single outlet for oil products in almost all developing countries. The countries reviewed are no exception and the bulk of their future incremental demand for liquid fuels is likely to stem from growth in the movement of goods and people.

Public transport is paramount in the lower-income countries and in those where strong policies exist to restrict private car ownership. Road vehicles dominate transport, except in China and India where for historical and geographical reasons the railways are very important.

Vehicle ownership moves roughly in line with increased income but with lower-income countries such as China, India, and Indonesia, on an earlier, steeper part of the motorization curve than, say, Brazil or Malaysia (Table 2). There is, however, a wide disparity in car and motorcycle ownership among countries at much the same income level. Urbanization tends to accelerate motorization; vehicle ownership is much greater in cities than in the countryside. Government policy is also very important in moulding the rate of growth and pattern of vehicle ownership. The ownership of motorcycles increased rapidly in India after the government liberalized their manufacture in 1984.

The level of car ownership tends to be higher among these countries than in lower-income OECD countries when they were at similar levels of GDP per capita. For example, compare the current level of car ownership in Malaysia at 90 per thousand people with 40 per thousand in Greece in 1973, even though Malaysia's current income per head is less than Greece's at that time. This higher level of motorization must be largely the result of the rapid decline of car prices in real terms in the post-war period combined with the development of an international car market.

Table 1: Intensity of Energy Use (BOE/'000 US$)

Countries	1970	1980	1988
Brazil	3.0	3.1	3.6
China	9.0	10.5	7.3
India	4.2	4.6	5.2
Indonesia	1.5	2.5	2.8
Malaysia	2.5	2.8	3.7
Pakistan	3.8	4.5	4.8
Philippines	3.4	2.7	2.3
Thailand	3.2	3.1	3.2

Table 2: Vehicle Ownership (1988)

	Vehicles per ('000 people)	GDP per capita (US$ '000)
Brazil	95	2035
China	5	565
India	12	310
Indonesia	46	596
Malaysia	288	1991
Pakistan	20	367
Philippines	21	627
Thailand	70	948

Source: Motor Vehicle Manufacturers Association of the United States, Inc. and Lawrence Berkeley Laboratory.

Malaysia and Brazil have the highest level of car and road vehicle ownership, reflecting not only their higher per capita incomes and long-established car industries but also a positive approach towards car ownership. Short-term income effects can also be significant; sales of cars declined steeply in Malaysia between 1984 and 1986 as lower personal incomes and foreign exchange controls adversely affected the import of car kits. In Brazil, however, vehicle ownership per capita has increased rapidly even during economic downturns; moreover, car ownership seems to have expanded faster at lower-income levels than in the other countries.

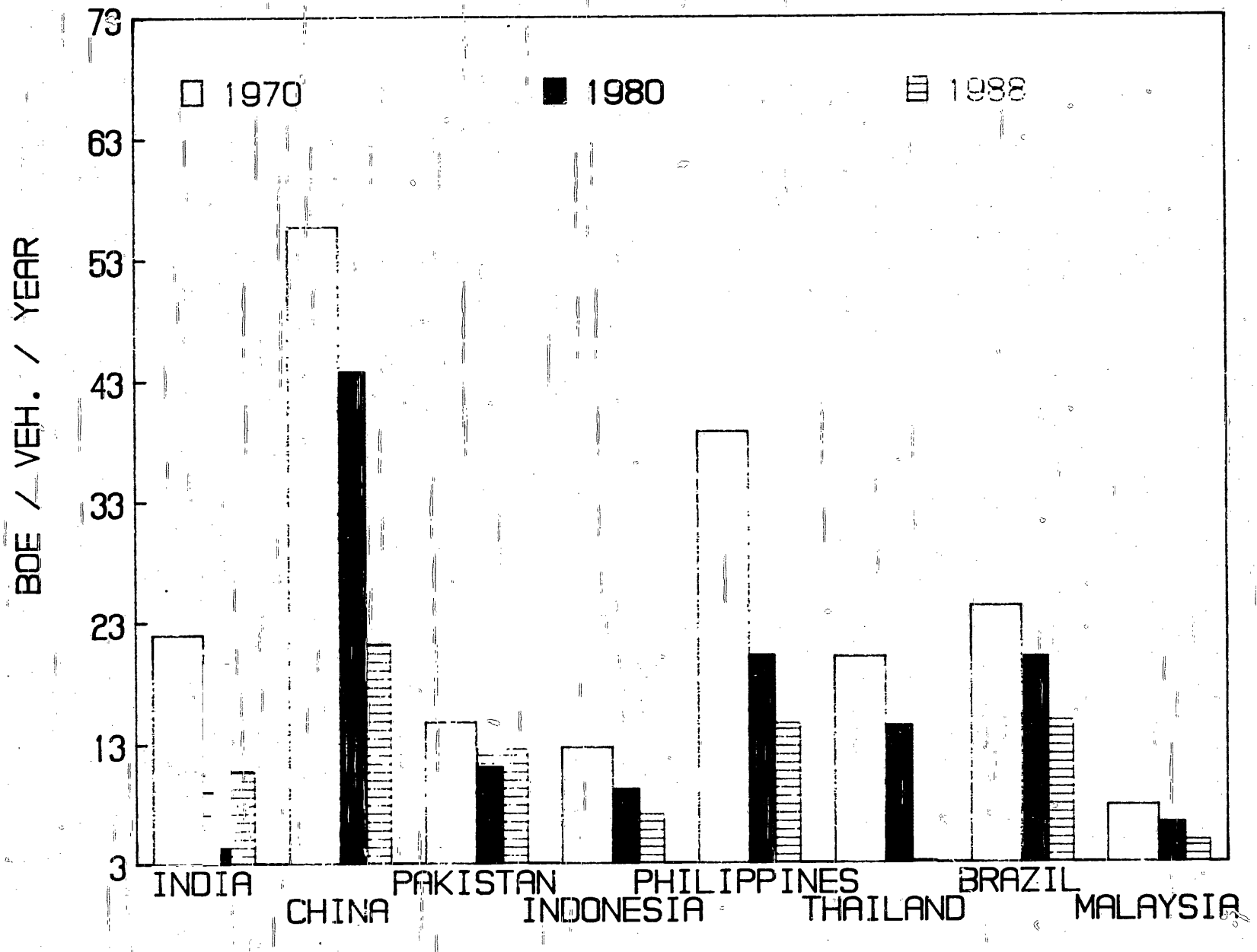
In Brazil, most of the vehicle fleet consists of cars and jeeps with motorcycles making up only 8%. In India, Pakistan and China and in the South East Asian countries motorcycles are used extensively; ranging from 24% of the vehicle population in the Philippines to over 70% in Indonesia. China has some 1.5 million motorcycles compared with only some 300,000 cars. Due to the large unmotorized population and very poor public transport system there is a heavy use of bicycles. As incomes increase a large segment of bicycle users are likely to advance to motorcycle use. The potential for growth in motorcycles in China is enormous. Already, the purchase of homegrown mototcycles is rapidly expanding in new enterprise rural areas. However, even if their numbers were to increase to the same proportion relative to the population as in, say Malaysia, this would mean only an additional 325,000 mb/doe fuel use because of their fuel efficiency.

Average fuel consumption per vehicle varies considerably with the composition of the fleet and with local conditions. One of the consequences of the rapidly-growing vehicle population in Brazil and elsewhere has been that fuel consumption per vehicle has fallen dramatically (Figure 2). This is due less to improvements in fleet efficiency than to a fall in average vehicle use--particularly for cars as ownership becomes more widespread. In the South East Asian countries fuel intensity has also been falling rapidly but this has had more to do with the substantial increase in the motorcycle population as well as the impact of improved car models. Average fuel consumption per vehicle in China is extraordinarily high, five times that of Malaysia and at the level of India, Brazil and the Philippines in the late 1970s. Most road vehicles in China are trucks, but as well their antiquated nature and their operating standards, combined with the generally poor road conditions and poor fuel quality, leads to high fuel consumption.

In general, cars in developing countries are less fuel efficient than those in the OECD. New Brazilian cars are at least 20-30% less efficient than comparable cars in Europe and Japan. The maintenance of a domestic car industry producing a wide range of old models, as in India, Malaysia and China, will tend to restrain efficiency improvements. Another inhibiting factor is the growing congestion in urban areas. In Indonesia the total vehicle fleet grew at over 15% p.a. over the last 15 years compared with a growth in paved roads of 10% p.a. This has clearly exacerbated the congested conditions on Java and there are similar problems in the major cities of all the countries concerned. Congestion and local pollution will place even more limitations on vehicle use in future although possibly not on their ownership.

Fuel efficiency is likely to continue to improve significantly. Slowly-rising fuel prices will encourage this through changes in ownership

FIG 2 FUEL CONSUMPTION PER VEHICLE



patterns and use; but the majority of efficiency improvements will occur largely as a result of progress in road vehicle technology.

The use of diesel fuel in road vehicles ranges from 15% in China to over 80% of fuel use in India (Table 3). Price and taxation policies are the most critical factors affecting the extent of diesel use. In general, diesel is encouraged fiscally and has been growing faster than gasoline. In Malaysia, where price subsidies on diesel have been removed the reverse is true. The preferred fiscal treatment of commercial or pseudo-commercial vehicles in, for example, Thailand and Indonesia has also encouraged growth in diesel demand. It seems likely, however, that diesel use in vehicles is exaggerated, particularly in countries such as Indonesia where favorable price policies encourage its use in other markets and for illegal export.

Table 3: Diesel Fuel as a Percentage of Total Road Fuels (1988)

Countries	%
India	82
China	15
Pakistan	75
Indonesia	51
Philippines	57
Thailand	69
Brazil	51
Malaysia	31

The Brazilian program to substitute ethanol from sugarcane for gasoline has been enormously successful in terms of volume. Between 1975 and 1986 the share of alcohol in total road transport fuel consumption increased from 1% to 27%. In 1986 the share of alcohol-based cars in total new car sales reached 90%. A substantial expertise in alcohol production and its use in cars has been established which could find markets in other countries. The economic success of the program is more doubtful and government perceptions as to its real value are changing. In line with government policy to reduce the use of gasoline, apart from subsidized alcohol prices, subsidized diesel prices encouraged substantial conversion of trucks from gasoline to diesel. These policies have had a dramatic effect on the fuel mix away from gasoline; in 1988 gasoline's share of the road transport markets was 48% compared with 73% in 1970.

The consumption of fuel by waterborne, rail and air traffic in these countries has increased only modestly in recent years. This is despite the growth in trade and tourism, increased industrialization, and the dispersed nature and large territorial areas in a number of the countries covered.

Rail transport is only of significance in India and China. Although coal is still the main fuel, diesel use is spreading in both countries. With an efficiency three to four times that of steam coal, the increased use of diesel seems likely to more than offset the expected increases in passenger and freight miles. Overall, energy consumption in this sector seems likely to remain static.

Air travel to and from and within the countries has increased dramatically over the last 15 years, increasing three-fold in terms of air passenger trips. Growth in air travel is partly related to national economic conditions and partly to international conditions. The introduction of more efficient aircraft and improved load factors has helped to keep fuel consumption down and this tendency seems likely to be even stronger in future. There is enormous potential for growth in air travel in all of the countries reviewed. Potential for increased sea travel also exists in China, Indonesia, Malaysia and the Philippines. The continuing introduction of more efficient aircraft and ships and improved operating procedures seems likely to prevent this growth in activity from being reflected strongly in fuel demand.

C. Urbanization and the Changing Demand from Households and Services

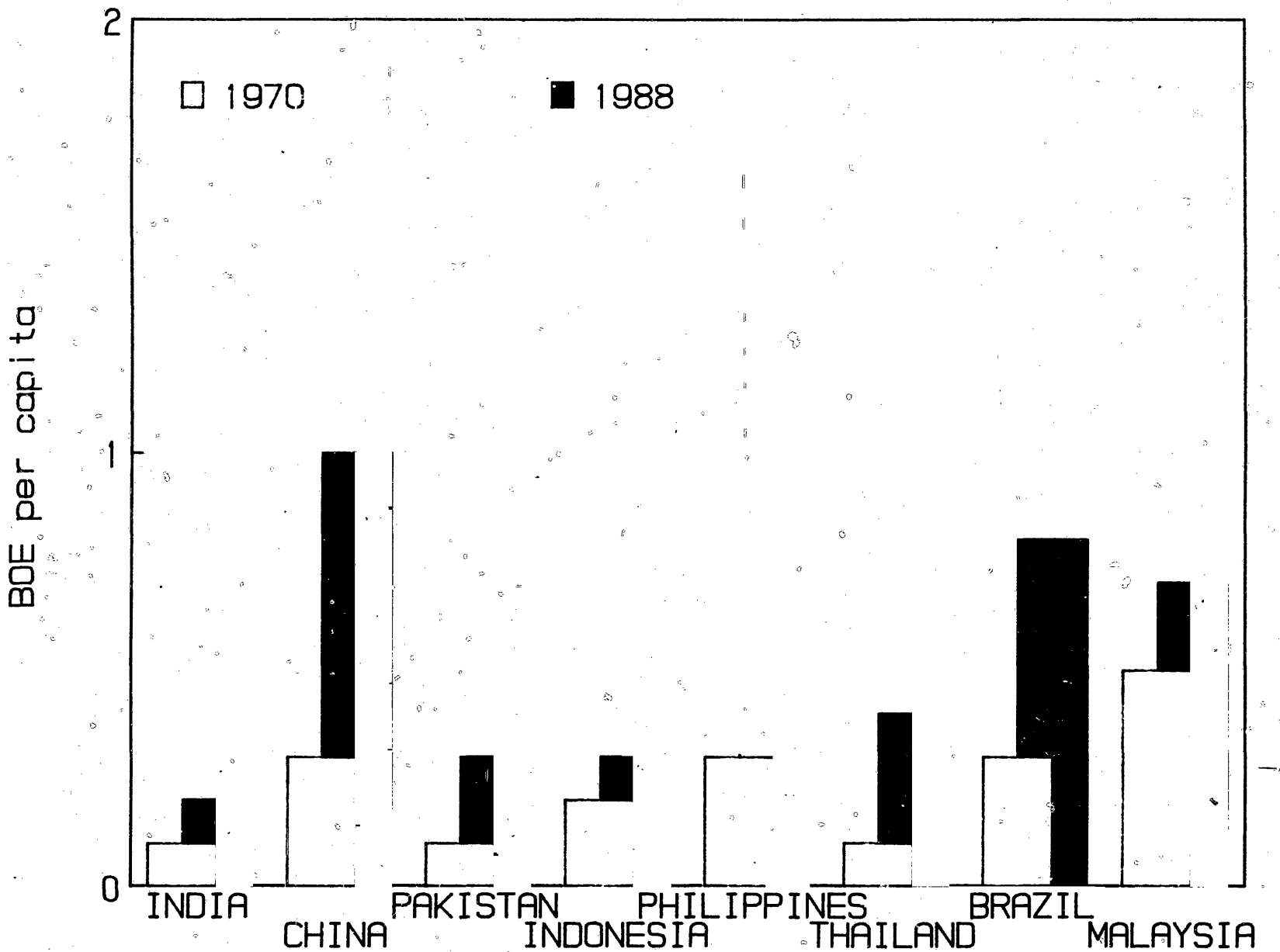
The growth of population and incomes and the spread of urbanization and modernization should all be reflected in the consumption of energy by households and the service sectors. These sectors represent a mixture of very different types, viz., rural and urban households, offices, hotels, government and other establishments, as well as agriculture which is often difficult to disaggregate with any reasonable degree of confidence. Nonetheless, although its composition and treatment vary widely from country to country it is clear that the largest single component of demand in this group stems from households--despite the faster growth in recent years by the services sector.

Households: The extent of energy use for household purposes is linked to population, household formation and size, income and the degree of urbanization. However, the continuing transition from relatively inefficient traditional fuels to commercial fuels and the impact of electrification and gasification tend to make the links less than straightforward. The energy used for space heating is usually about four times that needed for cooking on a per capita basis so that climate is also significant in determining overall levels of household consumption. In China, where more than one-third of the population needs space heating, consumption on an unrestrained basis should be higher than countries where space heating is scarcely needed at all (Figure 3).

The availability and price of energy resources within a particular country also play a major role in determining the level of consumption and its rate of growth. A rural Chinese household using balls of coal dust with an efficiency of only 10% is clearly going to have a higher recorded level of demand for a given use than a Pakistani household using natural gas with a 60% efficiency.

A substantial amount of traditional fuels is still used by households in all the countries reviewed. Their contribution ranges from under 30% in Malaysia to 60% in Brazil and nearly 90% in India. In countries where

FIG 3 ENERGY CONSUMPTION PER CAPITA



firewood and agricultural wastes are relatively abundant such as Malaysia, Indonesia outside of Java and Thailand, their contribution tends to fluctuate with changes in the price of kerosene and rural incomes. In these countries, rural households across a wide range of incomes have access to traditional fuels so that switching back out of kerosene and LPG is relatively easy when expenditure rises above some safe proportion of income, such as 5%. In other countries like China, India and Pakistan where traditional fuels are a rapidly depleting resource their continued use by households presents severe problems. In China, for example, biomass alone is quite incapable of meeting present rural needs let alone the increases from additional population growth. Somewhere in the region of half a billion Chinese lack enough fuel to cook three daily meals for three to six months of the year. Firewood is more expensive than grain; a sack of dried dung costs the equivalent of two months' income for a poor peasant. China, as well as India and Pakistan, cannot go on using biomass at the current rates for much longer. Ways to broaden its use or make it more efficient have had little impact. The use of biodigesters in India and China have often represented a burden to a poor farmer. In China their use only amounts to some 1% of total fuel use despite the years of apparently enthusiastic construction.

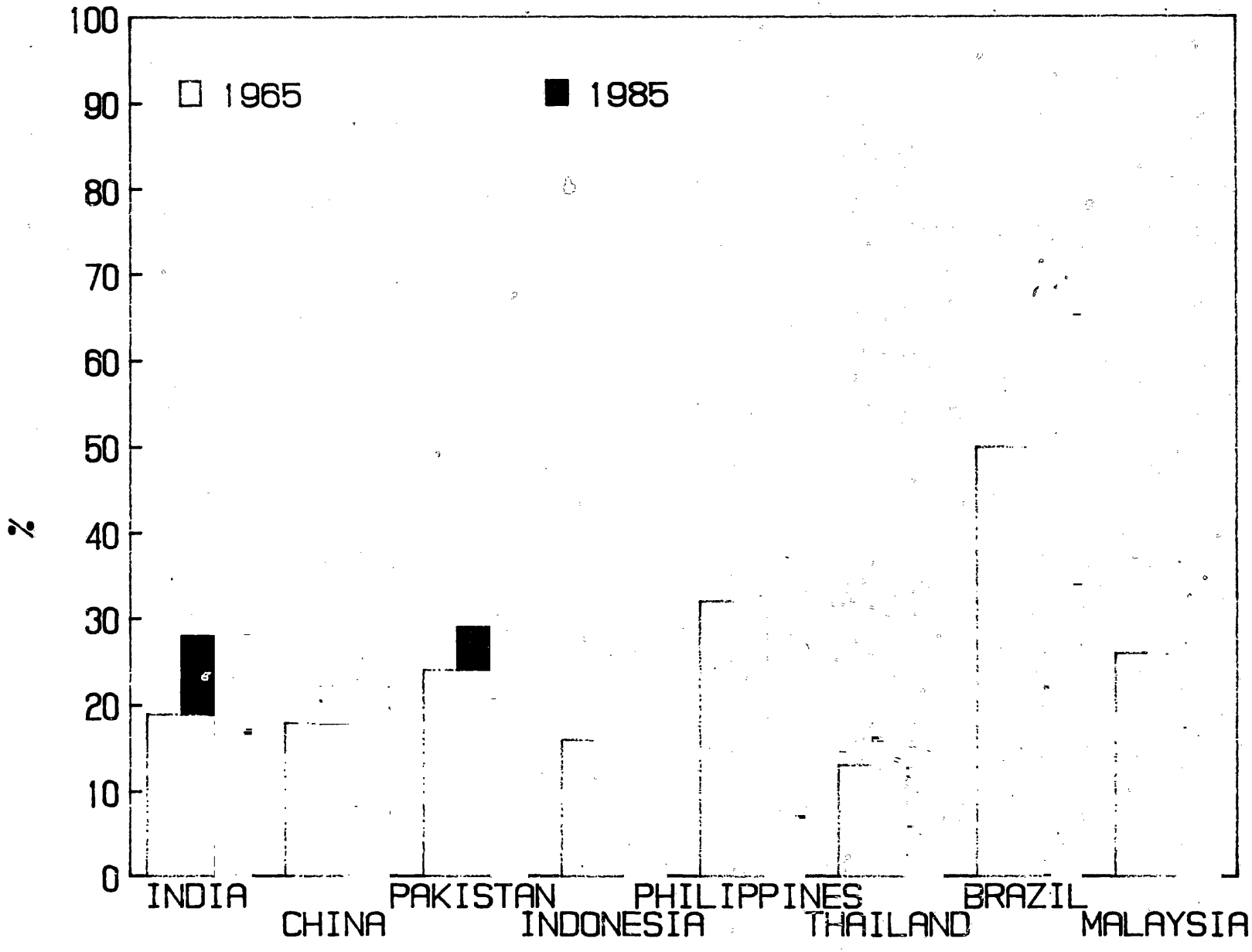
In general, because of its inefficiency, the higher the proportion of traditional fuels used the higher the total energy consumption per household. Total energy consumption per household in Indonesia is twice as nigh as in Malaysia, for example, despite per capita income being about one-quarter that in Malaysia. Commercial energy use per household in Malaysia is twice that of Indonesia.

In some countries, consumption per household appears to have stagnated in recent years and total consumption of energy is usually slower-growing than in the other main sectors. This can be explained by the fact that the growth in household income has been accompanied by a change in the fuel mix to more efficient fuels. This has been facilitated by the migration towards the cities with their greater availability of fuels--reflecting both the shift in available employment and the growth in the urban agricultural force who commute to the fields (Figure 4). Surveys of households with different income levels have shown that final consumption of energy goes up more slowly than income. As incomes rise, the shares of wood and charcoal fall and the shares of LPG and electricity and to a lesser extent kerosene and natural gas increase. Urban homes are more likely to use electricity and LPG than rural ones and less likely to use kerosene and wood. In fact, total energy consumption per household at a given income level is about the same in urban, rural or slum areas.

The substitution of more efficient electricity for kerosene and LPG used for lighting and the substitution of kerosene, electricity and gas for traditional fuels used for cooking and water heating has helped in all the countries to keep energy consumption growth per household down. In addition, reductions in subsidies and increases in kerosene and other prices have had a dampening effect on energy demand, particularly in rural areas.

As yet, natural gas is widely used by households only in Pakistan, which has the largest and most developed gas grid of any developing country. The lower price of gas versus competing fuels, in conjunction with

FIG 4 PERCENT OF URBAN POPULATION



urbanization and the rapid growth in availability from domestic sources, have resulted in large increases in gas use by households. A similar trend may develop in Malaysia and India as new gas sources and distribution systems are developed.

The spread of electricity connections, which have continued in most of the countries even through the economic difficulties of the early 1980s, has played a major part in keeping household energy consumption growth low. This effect has been achieved mainly through the efficiency gains of conversions to electricity use but also because of the low consumption of first-time connections in rural electrification schemes. Electricity use has been growing faster than any other source of energy for residential use. For electricity the share of expenditure rises with income (although this may be partly due to differential access between income groups). As household incomes rise, an increasing share of energy is used for other than basic cooking and lighting; largely for appliances such as refrigerators and air conditioners which in the main use electricity (Table 4). Electricity appears to be the energy source most strongly influenced by rising incomes, outside of Pakistan. Here growth in gas demand is outstripping that of electricity. This may be the case in future in Malaysia when the Peninsular gas system is developed and in India when the new grid is in place. In Thailand, the emphasis has long been on electricity use and it is the most important commercial energy used in urban households, representing about 45% of total consumption compared with less than 20% in Brazil. The low consumption of commercial energy per household in Thailand is a reflection of the substantial use of electricity.

Table 4: Percentage of Households and Services Energy Needs met by Electricity

Countries	1970	1980	1988
	(%)		
India	8	11	28
China	3	5	5
Pakistan	14	20	29
Indonesia	6	6	11
Philippines	19	41	58
Thailand	13	21	39
Brazil	45	52	41
Malaysia	13	15	47

Access to electricity does not necessarily lead to increased consumption because low incomes restrict the number of appliances, often initially to just one light bulb. Moreover, supply shortages and high prices can make extensive use unaffordable. Generally, however, with government policy permitting, ownership of appliances increases more rapidly than income, with refrigerators a priority. High-income households in most of the

countries reviewed use electricity today in much the same way as in, say, Europe but often with the addition of air conditioners. In Beijing in 1986, for example, 62% of homes had refrigerators (Table 5).

Appliance prices are falling relative to incomes so that ownership could reach higher levels at much lower-income levels than they did in OECD countries. The Malaysian experience is typical, with even low-income families having refrigerators and high-income families using electricity for water heating and air conditioning. The saturation level at present efficiencies could be about 1,500 kwh per customer without airconditioning. Wealthier consumers with airconditioning and a full range of household equipment could reach 3,000 to 4,000 kwh compared with around 100 kwh to 150 kwh for simple lighting use. However, electricity consumption may not reach such levels even with substantial rises in income. Most new appliances are of modern and efficient design; more efficient on average than the stocks of appliances in use in OECD countries (which includes appliances of older vintage).

To summarize, there are many factors working to change the average levels of household energy consumption. Those tending to push consumption upwards are:

- Increased income and urbanization.
- Greater use of appliances made possible by more widespread electricity supply.
- Continued low prices of kerosene, gas and electricity.

Those tending to push consumption downwards are:

- Increasing electricity connections to poor households.
- Smaller households.
- Substitution of more efficient fuels.
- Decline in the absolute amount of energy needed for cooking as a result of changing customs and more efficient stoves.
- More efficient appliances.

The next decade may see only modest increases in average consumption of energy per household and in some of the more wealthy countries possibly even a leveling off. However, increasing population and household formation will ensure that the demand for commercial energy continues to grow, although perhaps more slowly than other major markets.

The service sector: In most of the countries reviewed, energy consumption by the loose collection of shops, hotels, offices and government buildings that comprise this sector has been growing faster than consumption by households. Much of this growth has been linked with urbanization and the growth of the bureaucracy. Energy is used mainly in the form of electricity for lighting, airconditioning and power. An exception is Pakistan where gas plays a major role. Oil fuels are used largely for water heating and standby power generation but generally represent less than 30% of energy use in the sector. The heavy space heating load that many northern hemisphere OECD countries have in this sector is largely absent, except in parts of China where coal is used extensively.

Table 5: Electricity Appliance Ownership and Income in Urban Areas (Percentage of household)

Cities/Countries /Income Level	Refrigerators	Air Conditioners	Water Heaters
Kuala Lumpur (Malaysia) a/			
(M$/month)			
150-299	13	0	0
300-599	50	0	6
600-999	65	1	6
1000-1999	79	10	14
2000-4999	87	23	31
5000+	96	79	50
Manila (Philippines) b/			
Low	15	0	-
Middle	63	2	-
High	93	20	-
Beijing (China) c/			
Average	62	n/a	n/a

Sources: a/ Socio Economic Research Unit (Malaysia).
b/ Philippines Ministry of Energy.
c/ Jayant Sathaye, "Urbanization and Modern Life Style: Implications for Fuel Use," Lawrence Berkeley Laboratory Report no. 26260, 1988.

The intensity of energy use appears to have fallen in this sector, mainly due to the growing use of purchased electricity. In South East Asia, small businesses seem to consume around 900 kwh per connection with saturation likely to be reached at around 2,500 to 3,000 kwh. The intensity of energy use seems likely to continue to fall with the spread of more efficient equipment, especially for lighting and airconditioning, and the savings available from modern buildings. Energy consumption growth in this sector will be significantly affected by the success or otherwise of government plans to reduce the importance of services and the bureaucracy generally. The future consumption pattern is likely to be one of continued substitution of electricity for oil products and improvement in energy intensity.

Agriculture: This is a key component in the economies of all the countries reviewed although generally its share of GDP has been declining and its share of energy consumed is less than 10% in all countries. Energy for irrigation pumping accounts for much of the electricity used and farm equipment for the rest. The latter is usually for crop drying and may use largely traditional fuels as in China and Indonesia; but this activity is increasingly depending on commercial oil products. The use of diesel in tractors, other farm vehicles and fishery plant and equipment is not always recorded as agricultural use in some countries; in others its use is probably exaggerated. Thus, the basis of measurement for projection of future trends is uncertain.

Providing economic conditions allow it, the fast growth of energy-intensive agriculture that is already taking place in many of the countries will continue and spread. The impact on demand for commercial energy in China of less labor-intensive agricultural practices combined with reduced use of traditional fuels could be enormous.

D. Industrialization and its Impact on Energy Consumption

Industrial use of energy accounts for the largest share of final energy demand in all the countries reviewed, ranging from 34% in Malaysia to over 50% in China and India. Industrializing countries need energy to meet both domestic demand, largely focused on infrastructure, and exports (generally commodities and manufactures).

In the past, energy consumption for production of basic industrial materials appears to have grown faster than that of national income up to around $5,000 per capita, after which consumption for this purpose has leveled out. This is well above the per capita income level of any of the countries studied which would indicate that their future growth of energy for industrial purposes will be rapid. However, continuing technological improvements, changing demands and fuel conservation substitution practices could temper this growth considerably.

A major difficulty in analyzing industrial use of energy is that the volume of energy used is often uncertain. There are problems of definition and reporting for a sector which includes a wide variety of manufacturing processes as well as the mining and construction industries. In addition, the energy use of cottage industries is often indistinguishable from that of households, although their significance to industrial activity can be substantial. Indonesian industrial production, for example, still rests largely on over one million small-scale enterprises scattered over the

archipelego, which between them employ nearly 80% of the manufacturing work force.

There is also a surprisingly high level of traditional fuels in use, ranging from around 10% of total industry consumption in the Philippines to perhaps 60% or more in Indonesia and Pakistan. The use of these fuels is not confined to cottage industries. Much of their input consists of agricultural wastes such as bagasse, used in food processing plants, and firewood and charcoal, used in brick and ceramic factories, and, in the case of Brazil, in iron ore smelters.

Bearing in mind the uncertain quality of the data on which the projections are based, it is projected that manufacturing will continue to increase its share of industrial output but that mining and energy will remain important, particularly in China, Indonesia and Malaysia. In the latter two energy-exporting countries, however, there has been a move away from oil, gas and chemicals to other materials and manufactures. This is expected to continue as envisaged in government plans in several countries.

Historically, economic growth has been accompanied by improvements in fuel efficiency as a result of the installation of larger, more efficient facilities and better management. In most of the countries surveyed, fuel efficiency in the industrial sector is still low by international standards. China is an extreme example where existing production techniques and equipment are still mainly at the level of industrial countries in the 1950s. The continued heavy reliance on coal, usually in a raw state, is another major reason for poor efficiency as well as being the cause of serious pollution. The two largest industrial fuel users in China are chemicals and metallurgy and both are extremely fuel inefficient. One-half of the energy input of the chemical industry is consumed by synthetic ammonia plants with an average consumption of some 119MJ per KgN compared with 30-40 in a modern Kellog plant. In metallurgy a high price is still being paid for the earlier "small is beautiful" philosophy but, even in the newer, larger steel plants, coal consumption per ton of steel is often twice that of modern practice elsewhere. The energy industry itself is also a major and highly wasteful user of energy; own consumption and losses accounted for 1 mb/doe in 1987, about 19% of total industrial consumption.

Even in a country with a much higher per capita income, Brazil's industrial efficiency is low and, moreover, the intensity of energy use by industry has scarcely changed during the 1980s. For example, in the early 1980s, the six most energy-intensive industries used on average 50% more energy per unit of output than in Sweden. The Brazilian manufacturing industry is still heavily dependent on primary materials, reflecting the priorities of the second national development plan. However, within this bland picture changes have been occurring. There have been improvements in efficiency in major industries that have helped to partially offset structural changes, particularly in the paper industry where there are large mills with foreign participation (Figure 5). 1/ This has occurred despite subsidies for

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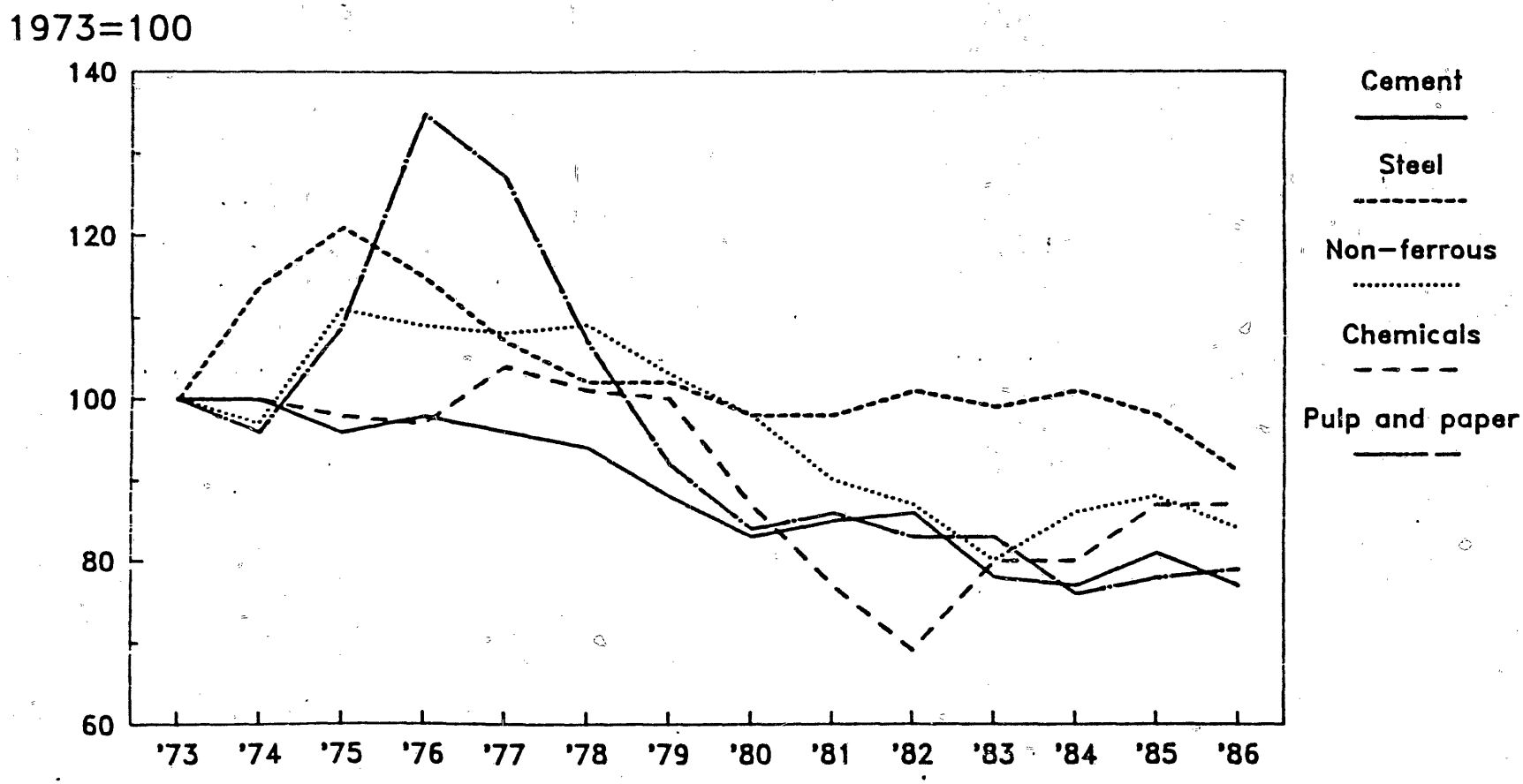
1/ Electricty counted at primary heating value; charcoal and bagasse included.

FIG 5 INDUSTRY ENERGY INTENSITIES IN BRAZIL

Energy consumption per tonne of product



industrial electricity and fuel oil.

In Indonesia, commercial energy intensity increased through the 1970s (Figure 6) as the economy expanded and as plants using commercial fuels became more widespread. Since the early 1980s, however, energy intensity has declined as more efficient, larger plants have been introduced. However, continued self-generation of electricity and the subsidies given for diesel have tended to work against the introduction of better practices and substitution. Improvements in energy efficiency and substitution have also been limited in captive units because of the lack of funds necessary to introduce costly energy-efficient technology.

Energy intensity in Malaysian industry has declined throughout the 1970s and 1980s. There were one or two upward blips in the mid-1980s but these were probably due more to the effects of the decline in the world price of commodities that Malaysia exports (i.e., rubber, tin, coconut oil, etc.) than to any changes in utilization. Malaysia's performance is a reflection of the more advanced nature of its economy and the greater emphasis on light industries such as electronics.

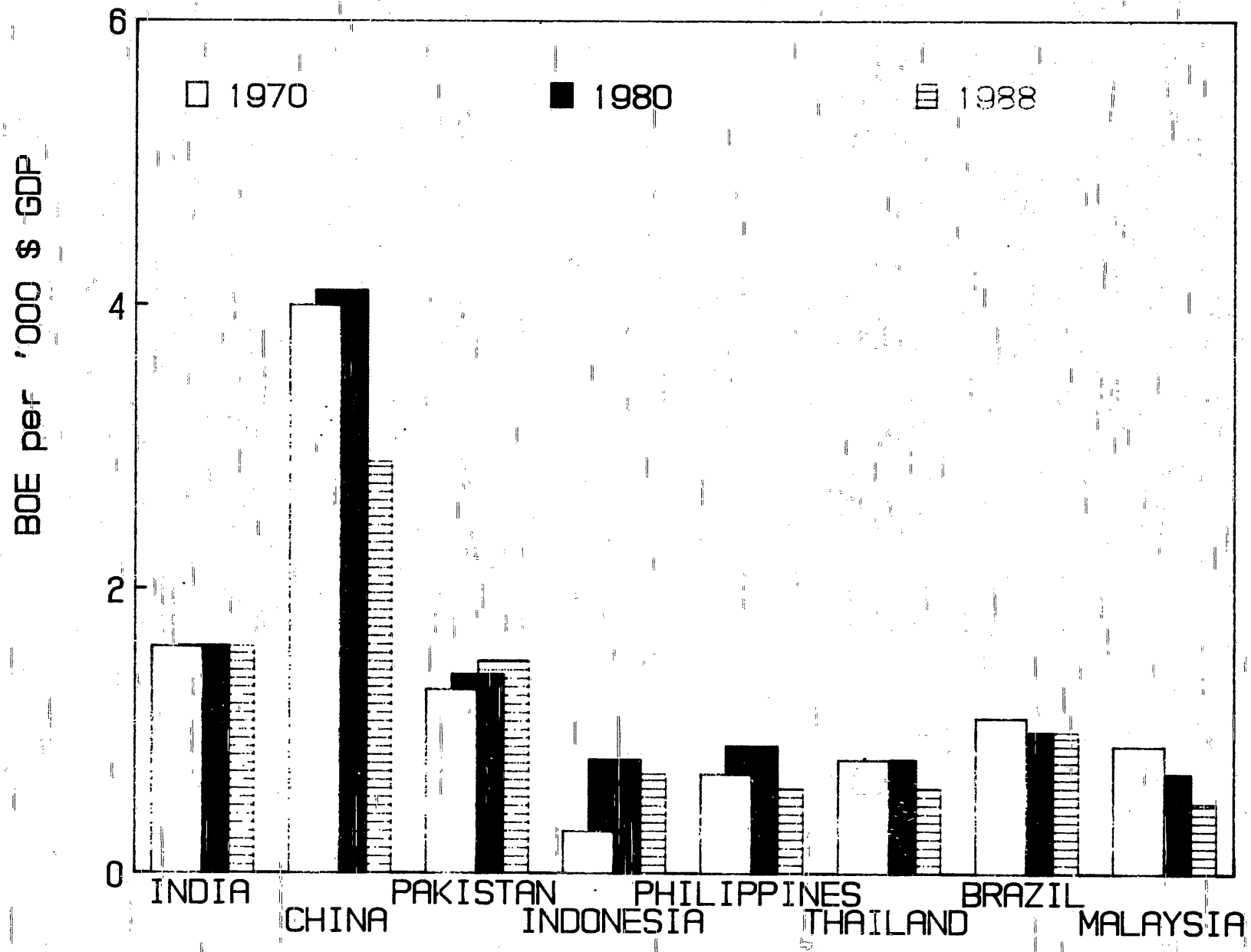
For Indonesia and Malaysia, both oil-exporting countries, some distortions in the general pattern of improving energy intensities tend to occur because of fluctuations in their oil exports.

Thai industries use a wide range of fuels including lignite and natural gas. The use of fuel oil is expected to decline over the next few years as greater use is made of solid fuels and gas, in the cement industry in particular. Major industries have in recent years reduced their energy intensity significantly by greater use of electricity. A major part of the electricity used is in a relatively few, but heavily energy-intensive, industries such as metals, cement and textiles. Largely as a result Thailand has one of the lowest commercial energy intensities of all the countries surveyed.

In Pakistan, energy intensity appears extremely high. The numerous small and antiquated factories and the use of poor quality coal may be countering the effect of the widespread use of efficient gas by most major industries. It is, however, more likely to result from problems of definition and reporting.

Economic growth in the Philippines is being diversified away from heavy industry which should slow down the growth in energy demand, largely oil, for industry. During the 1970s the Philippines was one of the first developing countries to adopt a comprehensive policy of energy conservation and demand management. In the late 1970s and early 1980s, energy intensity per unit of industrial sector GDP declined and although it increased in the mid-1980s with renewed economic activity, it has remained low. The small increase in intensity was largely due to substantial increases in the use of fuel oil by industries such as cement. Liberalization and privatization, providing greater incentives to use plant more efficiently and rapidly-growing use of purchased electricity point to a fast rate of decline in energy intensity in the future.

FIG 6 COMMERCIAL ENERGY INTENSITY IN INDUSTRY



The Indian government's policy of self-sufficiency and economic growth spread evenly across the regions has led to investment in energy-intensive industries such as chemicals, paper and metals. In many cases electricity has been the only means to provide these industries with the energy they need. Nonetheless, the mass of inefficiently-operated and aging plants, combined with the most widespread use of coal in industry outside of China (over 50%), serve to keep the energy intensity high. The situation is unlikely to improve rapidly over the next decade due to these technological constraints and to the cost-plus pricing system. In the longer term, as production priorities shift and some coal is replaced by gas (possibly from environmental considerations as well as pricing policy changes), intensities should move towards levels in other comparable countries.

In most of the countries reviewed, the intensity of electricity use in industry has been increasing while the intensity of total energy use has fallen. This trend seems likely to continue as lighter manufacturing and more modern technologies are put in place. Providing the generating and distribution networks are developed adequately, the share of electricity in most of the countries is likely to increase substantially to beyond the current level in Brazil, of around 25%.

Most of the countries reviewed, with the exception perhaps of the Philippines and Thailand, are continuing to include heavily energy-intensive plants within their development plans. If these planned investments go ahead it will tend to push energy intensities up. However, if manufacturing output grows at past rates the bulk of plant will be of state-of-the-art technology by the end of the century. Thus, the mix of plant should be more efficient than that in the OECD countries with their substantial stock of old technology plant. Such technological leapfrogging is critical to improving future efficiencies. Success will depend on the ability to transfer, disseminate and maintain these new technologies and on the improvements in integrated construction and management that they require.

The future demand for industrial energy will depend largely on how energy pricing policy develops. This will have a critical impact on interfuel substitution and the rate of adoption of more energy-efficient technologies. In a buoyant world economy there will be emphasis on low-cost, efficient export-orientated industries and moves to higher technology areas supported by heavier industries using the latest technologies. The wider use of gas in industry seems likely in almost all the countries reviewed, including China. Together with the inevitable growth in electricity use, the wider use of gas will improve energy intensity significantly in the medium to longer term. The movement out of traditional fuels by small enterprises may serve to work in the opposite direction to intensify commercial energy use. This will, however, represent only a minor influence as the bulk of traditional fuel use in the agriculturally-based industries is unlikely to be substituted for these uses and may even increase in these industries with an increase in suitable processes and greater environmental consideration.

China and India, with their extensive use of coal, face great difficulties in improving energy use in their industries. Elsewhere, with economic stability and rational pricing policies, efficiency improvements could be dramatic and at a faster rate than in OECD countries in the past.

E. Electrification: The Pacesetter

Electrification is regarded as the pacesetter for economic and social advancement in most developing countries, as it once was in the OECD countries. Its generation represents the fastest growing source of demand for energy and is the largest single energy market in most of the countries reviewed.

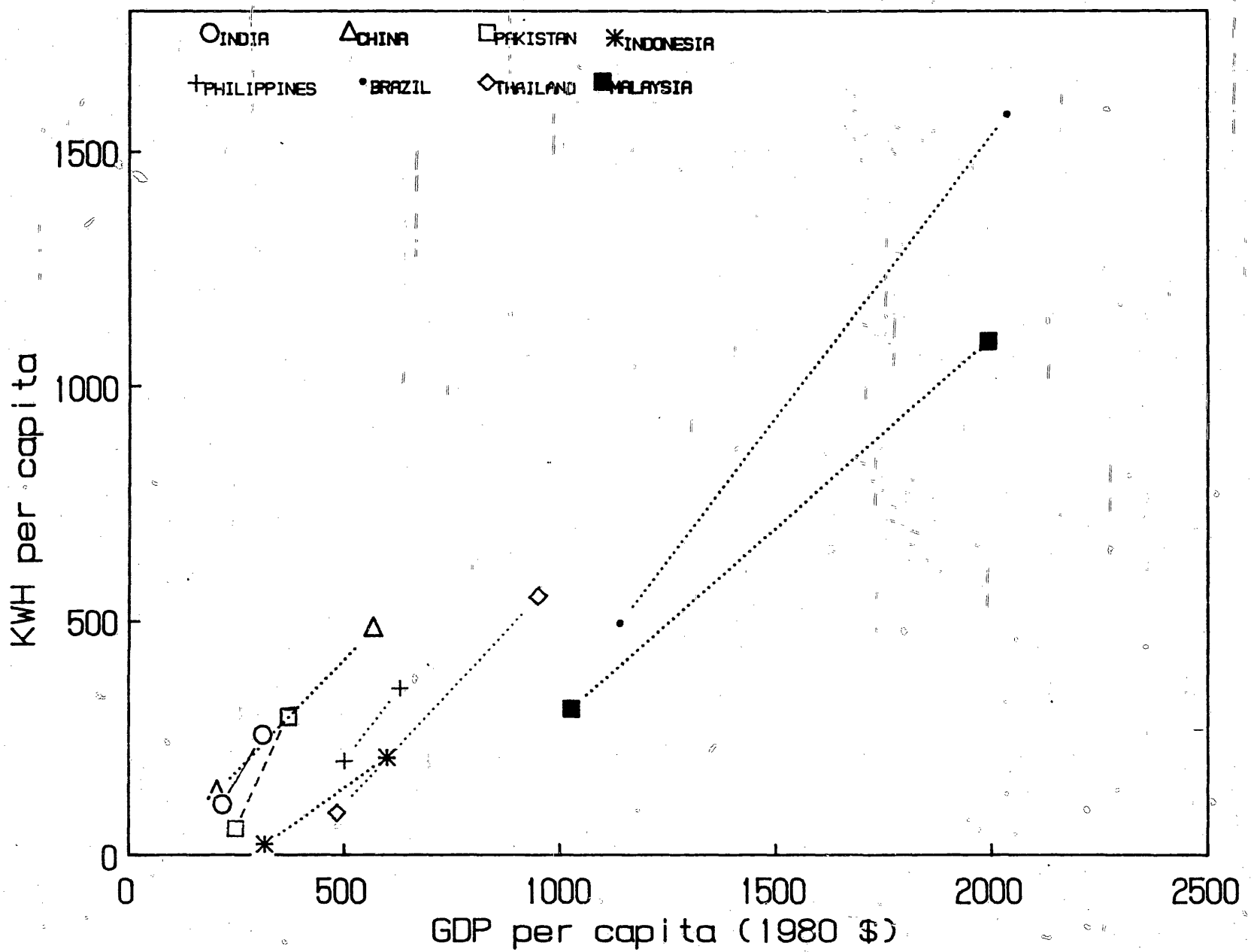
As the countries have developed, electricity consumption has grown considerably faster than GDP due to the mechanization of industrial and agricultural production and the spread of electricity connections to households and services. In Brazil, for example, electricity-intensive industries such as aluminum smelters were encouraged to use relatively cheap hydro power and many other industries substituted electricity for imported oil. In all the countries reviewed electricity has been sold at less than its full production cost and this has encouraged its use by industry and amongst all levels of the population.

Electricity consumption between 1970 and 1988 grew at over 8% p.a. in all countries except the Philippines. The fastest growth occurred in Indonesia, albeit from a very low base. Electricity consumption generally grows much faster than GDP in times of strong economic growth but also seems to increase in times of little or no growth; or even when there is a decline in GDP as in Malaysia in 1985 and 1986 or in Brazil in 1982 and 1983. There is clearly much pent-up demand for electricity awaiting expansion of electricity connections.

The growth in per capita consumption of electricity in China (Figure 7) is particularly remarkable because much of the rapid growth of GDP in the 1980s was in agriculture and in industries that were not particularly energy-intensive. This growth was largely stimulated by rural electrification schemes and the spread of irrigation pumping by electricity. Indeed, without the dampening effect of chronic shortages and rationing, it would have increased much more rapidly. Brazil has the highest per capita consumption, reflecting its higher income and degree of urbanization. These factors are also reflected in Malaysian and Thai consumption. Indonesia is at the lowest end of the per capita consumption scale. This is partly due to under-reporting but is also a reflection of the low level of connections and the small industrial base. Only 6% of rural and 35% of urban households have official utility supplies compared with 82% and 70%, respectively, in the Malay Peninsular.

The existence in Indonesia and Pakistan of substantial private and unofficial generation of electricity represents a potential pool of additional demand on central utilities which will eventually change the generating mix. As grids have spread and supply has become more reliable in all countries, the proportion of self generators in total capacity has fallen steadily. In Indonesia, around 50% of capacity is privately owned, some of it attached to major industries and often of substantial capacity. At the other end of the electrification scale, in Malaysia, the share of privately-owned capacity is only 5% or so. In Indonesia, for example, tariffs set by small-scale entrepreneurs are said to be twice as high for an inferior quality of supply as those set by the central utility. Most of the self generators use oil, although in sugar-producing countries such as Brazil and the Philippines,

FIG 7 ELECTRICITY PER CAPITA, 1970, 1988



bagasse is used.

In the early stages of expansion to meet electricity growth, say up to 2 or 3 GW, heavy reliance is placed on diesel generators with fuel oil-fired steam plant and some hydro (when available) used as base load. As the system develops, the availability of indigenous energy resources has a growing influence in the choice of generating plant, although the nature of the system, the level of urbanization and the size of the market remain major influences. Thus, the mix of generating capacity is extremely varied over the countries reviewed (Figure 8).

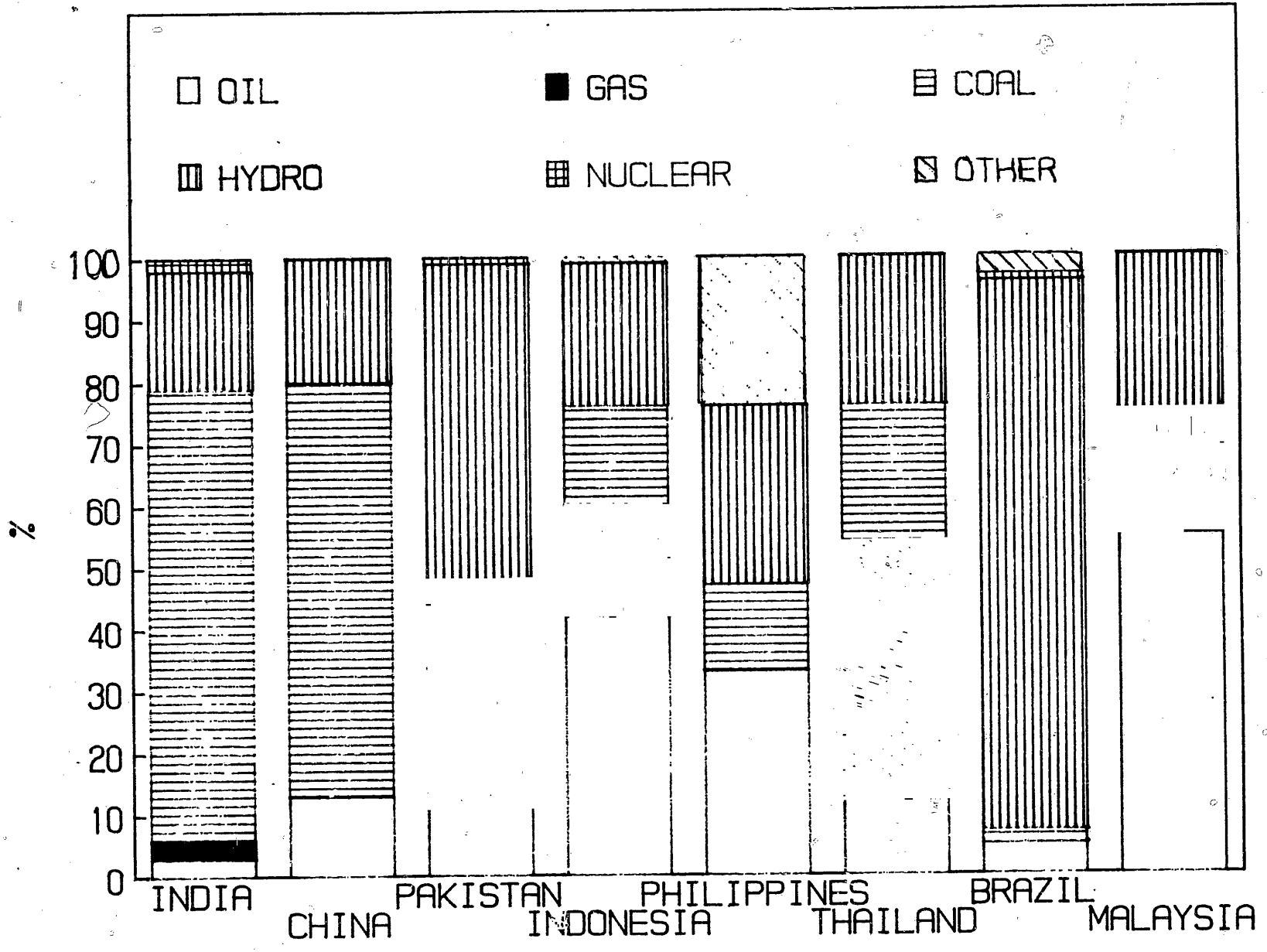
China has the largest generating system of any developing country. The current government forecast is for 240 to 265 GW by 2000. This represents roughly the same rate of growth as in the last decade but is likely to be inadequate to meet demand growth or to end the power shortages and rationing that are commonplace at present. Over 75% of generation is from thermal plants, largely coal. Current plans emphasize a continuation of the switch out of the remaining oil-fired plant to coal in order to save oil for export. This strategy presents severe difficulties with respect to sulfur emissions and coal delivery. Although the massive Three Gorges hydro project may go ahead and there is continued interest in nuclear power, with two plants planned to be in operation in the 1990s, China seems to have little option other than to increase its reliance on domestic coal, which is abundant and relatively cheap.

Growth in electricity use has been particularly rapid in Brazil, encouraged by low prices and subsidies; the share in the total direct market increased from 6% in 1970 to 16% in 1988 with 67% of the population now having access to the grid. As a result, capacity has had to expand almost five-fold with over 80% based on hydro and almost all generated by public utilities. Generation from oil and coal has grown in recent years but remains relatively small. Nuclear power came into use in 1985 but its impact has been minimal. Hydro seems likely to continue to provide the bulk of Brazil's electricity well into the next century.

Pakistan has relied on a mixture of gas and hydro-generated electricity for many years. In the 1970s they together provided roughly equal amounts but during the 1980s hydro grew much faster and now dominates. There is a very small contribution from nuclear power and fuel oil use has grown in recent years because of the increasing scarcity of natural gas. Indigenous coal may also be used more widely for power generation in future. There is still a substantial amount (around 20%) generated by self producers. The very high level of "losses" still need to be addressed. Demand for electricity has been growing very fast. The substantial capital needed to meet demand growth and allay serious power shortages has led to interest in stimulating private investment.

Dependence on oil in the Philippines has declined through the 1980s with generation from hydro and geothermal and coal having expanded. Still, oil-fired plants produce nearly 50% of all electricity. There is widespread potential for the greater use of geothermal, a low-cost option, and indigenous coal. There is one nuclear plant with little prospect of coming into operation in the near future. Self-production is widespread because of the abundance of isolated islands and large mining activity. However, electricity

FIG 8 ENERGY USED IN POWER GENERATION, 1988



losses in the Philippines are fairly high. The average transmission/distribution loss is above 20%. New programs to reduce losses are now underway.

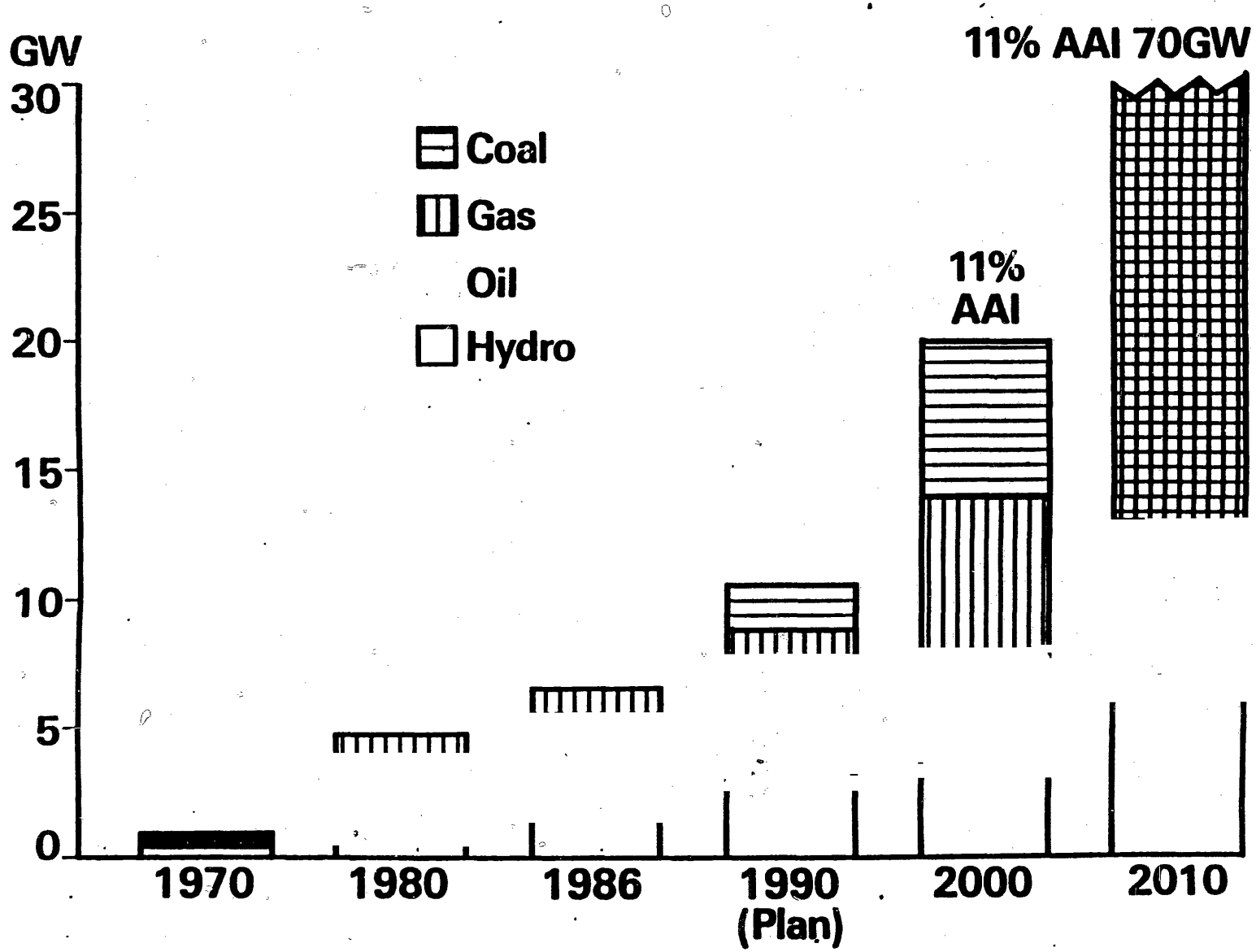
Electricity has a unique role in India through the policy of spreading self-sufficiency and economic growth evenly amongst regions. In most cases electric power is the only means to provide these industries with the power they need. Power growth is also seen as a way to contain growing demand for oil products. In spite of large investments in the expansion of capacity, economic growth continues to be hampered by widespread power shortages. Coal is the major source of electricity and its use is likely to grow as more minemouth plants are built. Hydro has also increased in recent years and there is substantial potential for future development. Nuclear's overall contribution is small although very significant in some areas. The government's approach to power shortages is to concentrate on fossil-fueled plants that take less time and capital to build than hydro and nuclear. There is considerable self-generation of electricity using coal and oil; recently the government liberalized its policy to allow industry to install its own diesel generators. This, in conjunction with the wider use of fuel oil by utilities for peak generation, has meant a growing demand for oil products. Natural gas is already used in a small way. Its increased use depends on the construction of facilities to develop indigenous gas which requires heavy investment. Once in place, however, its use should significantly reduce the time taken to bring new plant on-stream and also help to reduce the use of imported oil.

In Indonesia the share of electricity generated from hydro and coal has grown in recent years, however, in this major oil-exporting country oil is still used to generate over 60%. Much of the existing plant is run inefficiently due largely to the lack of a fully-integrated grid and the scattered nature of much of the generation and demand. Many of the fuel oil-fired plants used by the utility are inefficient and overdue for replacement. The scope for saving through the replacement of these generators and in reducing the very high transmission losses could ease the burden of new capacity construction. This burden could still be enormous; if consumption continues to grow at the rate of recent years, about 70 GW of capacity would be needed by the turn of the century (Figure 9). 1/ This is more than the United Kingdom's present capacity and represents a seven-fold increase. The government plans to base most future capacity on indigenous coal-fired plant and hydro with nuclear still an open option. However, most of the growth in demand is on the densely populated island of Java and much of the coal on Sumatra and Kalimantan with most hydro on Java having been already exploited. The substantial gas reserves off Java and elsewhere must eventually be tapped if the use of oil is to be cut back. In the longer term the development of an ASEAN grid may help to bring about the use of the substantial energy resources of South East Asia in a balanced and cost effective way.

1/ Source: Indonesian Ministry of Energy (historical and planned); International Economics Department and Shell International Company (projected).

FIG 9

IN ONESIA INSTALLE GENERATING CAPACITY



The Malaysian government is much further down the road in using gas for power generation. Large-scale use began in the mid-1980s and future incremental capacity will be based largely on gas or dual-fired, combined-cycle plant. Additional hydro is planned for the late 1990s and next century. Gas units have considerable advantages in terms of low initial outlay and the ability to be built in modular stages as well as using an underutilized resource. Realistic gas pricing policies have helped to encourage these developments which should gather momentum as the Peninsular gas grid expands. The "four-fuel" policy of the government encouraged the modest use of coal in the early 1980s but the introduction of large-scale coal plants now seems unlikely, particularly given the advantages possessed by gas. The installation of more efficient plant, an improved grid system and higher load factors should lead to significant savings in capacity additions as well as saving considerable volumes of oil for export.

Thailand, with a mixture of indigenous lignite, gas and hydro has managed to reduce the proportion of oil-fired capacity to below 5%; in the early 1980s fuel oil and diesel generated over 60% of electricity. Difficulties in making sufficient gas available may lead to a revival of fuel oil for power generation in the early 1990s. This could only be a stopgap measure and it has been planned to introduce additional coal-fired base load plants. These would have to be based on imported coal unless additional indigenous lignite deposits can be discovered. A more likely route leads, as with Malaysia, to the greater use of gas.

There is considerable scope in all the countries reviewed to improve the efficiency of generation and distribution. Technical problems such as low availability of plant, frequency outages, fluctuating voltages and poor maintenance are common as are losses and thefts of power. Total electricity system losses are over 20% in Pakistan and India and, except in Malaysia, Thailand and the Philippines, are well above the average in OECD countries. There are also severe problems in meeting peak demand in China, India, Pakistan, the Philippines. The non-availability of thermal plants, due to lengthy downtime, and of hydro, due to fluctuating water availability, often means that installed capacity ratings bear little relation to what is actually available, particularly at peak times. For example, China could save as much as 1 mb/doe of fuel if it were following the practices that are normal in the more advanced developing countries such as Taiwan (China) and the Republic of Korea.

A major problem that all the countries face is that of capital. In most, over 20% of the development budget has been devoted to the power sector --a proportion that represents more than 60% of the budget for all energy investment. This shortage of capital, particularly in the heavily debt-burdened countries, has led to varying degrees of interest and realism in attracting private power investment in all the countries reviewed.

Environmental issues have to date not been a major issue in power plant construction as they have been in the OECD countries, but they are beginning to surface. Hydro plants in China and Thailand have been delayed by public opposition. Use of nuclear power in the Philippines and Brazil has also aroused protests. The two main users of coal for power generation, China and India, will also eventually attract opposition to their widespread use of coal. Locally, it will manifest itself in the social and economic cost of

gross air pollution. At an international level the global concerns about CO_2 build-up and global warming will make themselves felt initially through public interest groups in the OECD countries using their influence with international lending agencies, as they have done already with large-scale hydro development. Although it seems unlikely that China or India could, or would be willing to, move substantially away from coal, a combination of public pressure and financial assistance may help to bring about a more efficient and cleaner use of coal.

III. POTENTIAL SUPPLY CONSTRAINTS AND ENERGY CHOICES

A. The Constraints

Between 1970 and 1988 some 13 mb/doe of additional energy was needed by the eight countries reviewed. Of this, 26% was provided by oil. This low average figure is in part a reflection of the heavy weights of India and China, where the largest share of the increment was taken up by coal, and of Brazil where hydro has been so important. Even so, an oil-exporting country such as Malaysia supplied less than 50% of its incremental energy needs from oil.

Despite improvements in energy use, it seems likely that an increment as large as this, and probably considerably more, will be needed over the next 20 years. In addition to the investment required to meet the growth in demand, additional investment will be needed to replace existing production capacity as it reaches the end of its useful life. The question is how much of a constraint will supplies be to overall energy development.

Energy supply is already a serious constraint in many of the countries reviewed and is often at the heart of their economic problems. Brazil is a prime example, with over 40% of public investment in the early 1980s accounted for by domestic energy investment. China has an enormous pent-up demand for energy which is severely controlled by supply, as witnessed by extensive shortages and rationing. In Pakistan, the stagnation in growth of gas supplies has led to severe gas shortages which have prompted the government to take measures to restrain demand growth through allocations by region and user. The result has been electricity shortages and increased oil imports. There are many other examples, from the single rickety nuclear plant that has to supply almost all of the Indian State of Rajasthan's electricity to the crippling effect of oil import bills in five out of the eight countries.

During the 1970s and early 1980s most of the countries, oil exporters as well as oil importers, promoted policies to diversify away from oil and to increase access to indigenous sources of energy. Although not universally successful, these policies have broadened the supply base and provided a foundation for future diversification.

The cost-effective development of energy resources is at the heart of successful economic development. In simple basic terms of the energy resource base available, commercial energy does not represent as much of a constraint as the access to capital needed for the exploration and development of energy resources in most of the countries, except perhaps in the Philippines. In practice, there are clearly many major problems in all the countries that will affect their ability to meet energy needs adequately.

Capital availability will continue to be a major constraint, with a third or more of public investment resources having to be devoted to the development of indigenous energy. Technological advance should be helped by the rapid introduction of new capital stock and a growing cross fertilization of energy technology and practice among the ASEAN countries and, for example, between Brazil and India.

In most of the countries reviewed, Malaysia, Indonesia and India are examples, pricing policies are slowly changing to reduce the discrimination between producers and consumers. Domestic prices are now being aligned to world market prices and to reflect the scarcity values of the resources. This is expected to contribute to the development of the energy sector in most countries reviewed.

As stated earlier, environmental considerations are already having to be taken into account where large-scale hydro works are contemplated and increasingly local and global issues of pollution will affect the pattern of energy supply.

Much of the energy supply system in all the countries reviewed is managed directly or indirectly by the State, largely through centrally-controlled monopolies. This has often seemed necessary to develop an adequate and broad supply base to ensure the availability of energy throughout the country at all economic levels. Sometimes it has led to inefficiency and waste of resources. However, the role of utilities and of state organizations is changing and a greater role is seen for the private sector in all the countries reviewed.

B. The Choices

Clearly the size and range of the commercial energy resource base varies considerably from country to country. The present pattern of energy use and whether there is a surplus for exports or not is a reflection of the resources available and the way in which their development has been encouraged in the past.

Coal: China is the largest coal producer in the world and an exporter with abundant reserves of reasonable quality coal able to sustain current production for over 100 years (Table 6). Although some coal reserves are found in all Provinces, two-thirds are in the north; the energy-short provinces south of the Yangtze have largely inferior coal deposits. This regional disparity presents a major problem, with the transport of northern coal to the south and substantial west to east movements involving costly logistics. The main dilemma for the future remains whether to concentrate on development in the north where costs are lower, or to reduce transport costs by developing the more costly reserves closer to consumption centers. Either way, China has little option other than to rely on coal for most of its energy demands. Foreign investment is being encouraged but generally prices are held artificially low, making it difficult to justify the levels of investment required unless there is access to export markets. The industry is technically very backward, distribution is a chronic problem, pricing irrational and policies in a state of flux. Nonetheless, the Chinese capacity for surprising achievements could well mean that production will reach and probably surpass the turn of the century target of 1,200 million tons of raw coal.

India, the other major producer of the group, also has abundant reserves. A massive investment program has favored large-scale, open-cast mines in recent years and these now account for over 50% of production. Partly as a result, coal quality has been declining steadily which has tended to reduce its economic attraction and also necessitated the use of increasing

Table 6: Coal Potential

Countries	Coal Production (Million Tons)	Reserves/Production (Years left at current production)
India	165	152
China	900	111
Pakistan	3	41
Indonesia	3	1,000
Philippines	1	53
Thailand	4	116
Brazil	5	182
Malaysia	neg	-

quantities of fuel oil for firing purposes. Nonetheless, coal seems destined to remain India's largest source of energy with the doubling of production feasible by the end of the century.

Elsewhere in the group, Indonesia also has extensive and substantial reserves of coal, although there is a good deal of uncertainty about their cost and quality. Most major new power capacity is planned to burn coal and it is still hoped that Indonesia can eventually become a coal exporter. The heroic levels of production once planned for the end of the century of 40 to 75 million tons per annum from under 5 million tons at present are not now likely to find the required investment. Nonetheless, coal remains a resource with potential to substitute for oil in order to keep oil exports at acceptable levels.

Coal use in Brazil is very low, largely due to its poor quality--although there are substantial reserves. Nearly all reserves in Pakistan are also of poor quality. In Malaysia, the economic viability of most deposits is doubtful; reserves in the Philippines are largely of lignite with limited potential outside of power plants close to the mines. However, in Thailand where reserves and production are mainly of lignite also, the role of coal in the energy sector is significantly greater than in the Philippines.

Natural gas: The development of natural gas is already a key, if not major, component in the economic and energy strategies of Indonesia, Malaysia, Pakistan and Thailand (Table 7). In China, India and Brazil the potential of their substantial gas resource base is starting to be realized and the 1990s should see rapid development in the use of gas in all the countries reviewed, with the exception possibly of the Philippines.

The potential for Malaysian gas to become a major source of domestic energy as well as a substantial foreign exchange earner is very favorable. Reserves are at least three time those of oil, with a reserves-to-production ration for gas of over 0.90, and with excellent prospects for new discoveries. Investment in gas has forged ahead in recent years with nearly 25% of domestic gas needs now being met by indigenous gas compared with 2% in 1980. The share in 2000 has been targeted at 40%.

Table 7: Natural Gas Potential

Countries	Natural Gas Production (000 mb/doe)	Reserves/Production (Years left at current production)
India	165	64
China	231	65
Pakistan	203	41
Indonesia	850	51
Philippines	0	0
Thailand	57	62
Brazil	95	21
Malaysia	280	95

Malaysian production costs are low by international standards and there is scope for both increasing exports and promoting rapid domestic market penetration. The near saturation of Pacific basin markets will prevent the development of many additional export outlets but should serve to encourage domestic use and substitution for oil. The latter already includes the conversion of gas to middle distillates for road transport and other uses. The completion of the final stage of the three-stage gas scheme to distribute gas over the Peninsular could more than treble or quadruple consumption by around the turn of the century.

Indonesia also has substantial gas reserves--at least twice those of oil--with relatively low production costs. However, due to the fact that they are mainly located away from existing centres of population and industry, the transportation and distribution is particularly costly. An aggressive development policy has made Indonesia the world's largest LNG exporter with gas production increasing sevenfold since 1975. The need to substitute gas for domestic oil production in order to maintain oil exports is well recognized but the government has yet to put together a workable policy. There seems little real alternative than eventually to follow the Malaysian model as it seems doubtful if long-term economic growth can be sustained without the development of gas for domestic use on a large scale. Thailand also has substantial but relatively high-cost gas reserves. Their current availability seems unlikely to support continued growth in the power market, which takes some 90% of gas produced. Major new developments are needed before Thailand can further diversify away from oil.

Natural gas is Pakistan's most heavily exploited energy resource, supplying some 40% of commercial energy needs. Although originally starting along the traditional route as a fuel and feedstock for fertilizer plants it is now widely used for power generation and in the industrial and residential markets. Pakistan has the most developed gas system of any developing country and is unique in its widespread use of gas in the residential market. Unfortunately, growth in gas supplies has been almost stagnant in recent years, resulting in severe gas shortages. Even with increased exploration, stimulated by the gas policy introduced in 1985, it seems likely that gas supplies will start to fall by the end of the 1990s, if not before. In the

long term the need to keep the system full may require the import of gas as LNG or by pipeline from neighboring Middle Eastern countries.

Resources of gas in Brazil are widely distributed although proven reserves are currently very modest. There are probably significant volumes of undiscovered gas available but as yet investment activity has been low. Major finds of associated gas have been made which are being pushed into the residential and services sectors and even into the transport market. There should be scope for intra-South American supplies. There is a current target to increase gas use to 275,000 mb/doe by the end of the 1990s--from the present 95,000 mb/doe--but this target appears unlikely to be achieved in the present financial climate.

The Philippines seem to have little in the way of gas resources and may become importers. In India, gas has only recently become an important commercial fuel but it probably has a more substantial resource base than oil. At present, gas supplies only 3% of commercial energy needs but could play a much more important role. Until recently, the bulk of associated gas, now produced mainly from the Bombay High field, has been flared because of a lack of infrastructure for processing and transmission. Initially, the government restricted the use of gas to fertilizer and chemical plants on the assumption that availability was limited. The discovery of non-associated gas has changed this policy and a 1,700 km pipeline is being constructed to take the gas from the west coast to the interior. As with oil there is probably substantial scope for increasing production, although there will be time lags and a need to rely increasingly on private risk capital.

Oil: At the levels of oil demand needed to fuel the high rates of motorization and urbanization expected, and the demands for generation of foreign exchange, there will be oil supply strains in all the eight countries reviewed. A freer investment climate and rapid technological change in exploration and development techniques will undoubtedly bring in new discoveries of oil and improvements in recovery rates. Nonetheless, the countries that now export, i.e., China, Indonesia and Malaysia could become net importers of oil by the end of the century unless effective efforts are made to conserve and substitute for oil (Figures 10 and 11). 1/ All the other countries in the group have some indigenous production, supplying from 4% in the case of the Philippines to 65% in India. Their proven reserves and the potential discoveries are generally adequate to maintain present production levels for a few years (Table 8), and even to increase them modestly in some cases. However, by the mid-1990s production seems likely to decline and the call for imports to increase even faster than at present--at a time when other non-OPEC oil sources will likely also be past their peak and prices moving upwards.

Production in the majority of existing fields in Indonesia, the second largest oil producer of the group, is declining and can only be

Insert Figure 10

1/ The figures present the forecast oil balances for Malaysia and Indonesia. We have derived these from an assessment of the future oil consumption and output paths based on different scenario assumptions for several key factors including economic growth, oil reserves and prices.

FIG. 10 MALAYSIA : THE OIL BALANCE

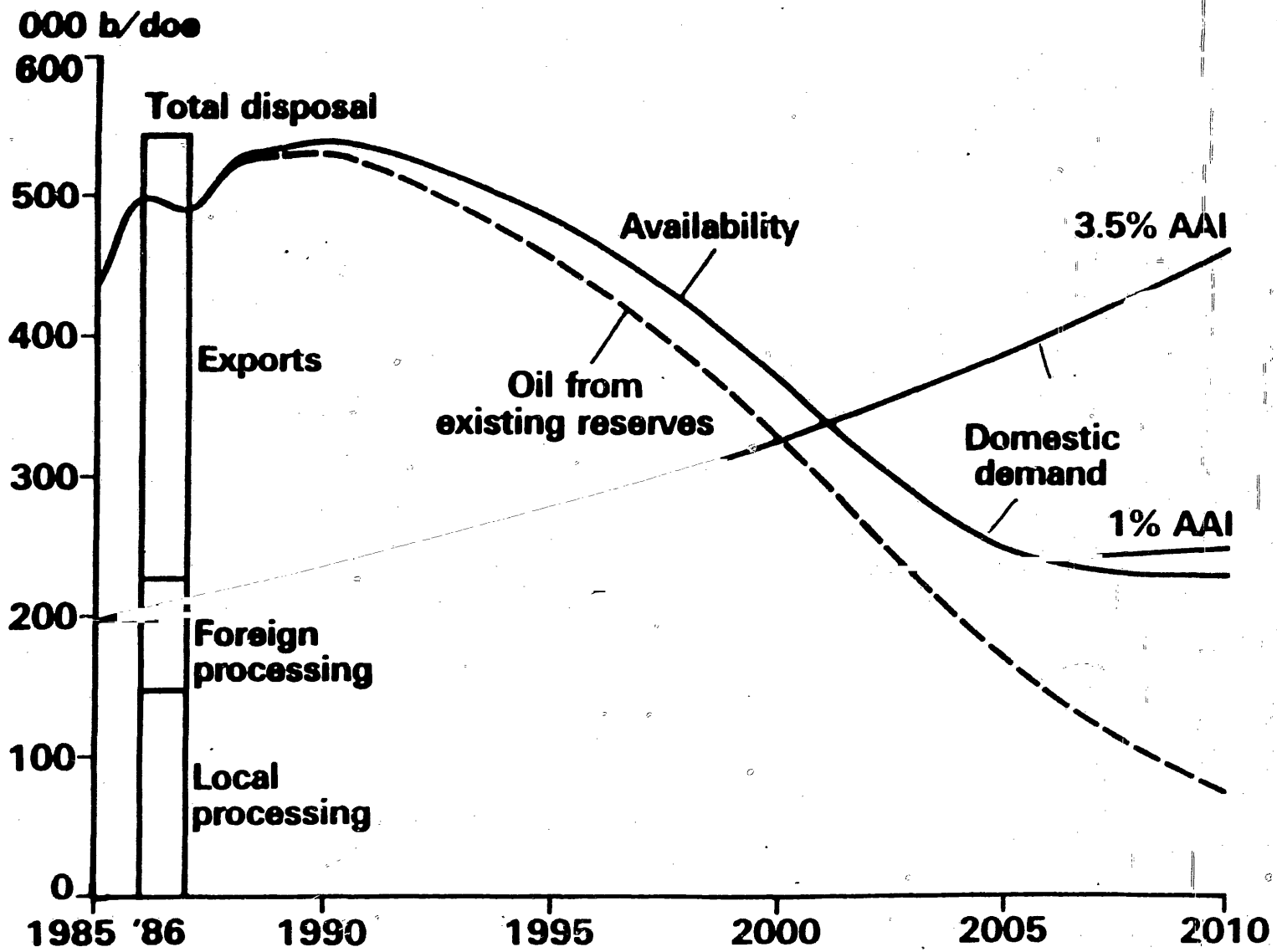


FIG. 11 INDONESIA: THE OIL BALANCE

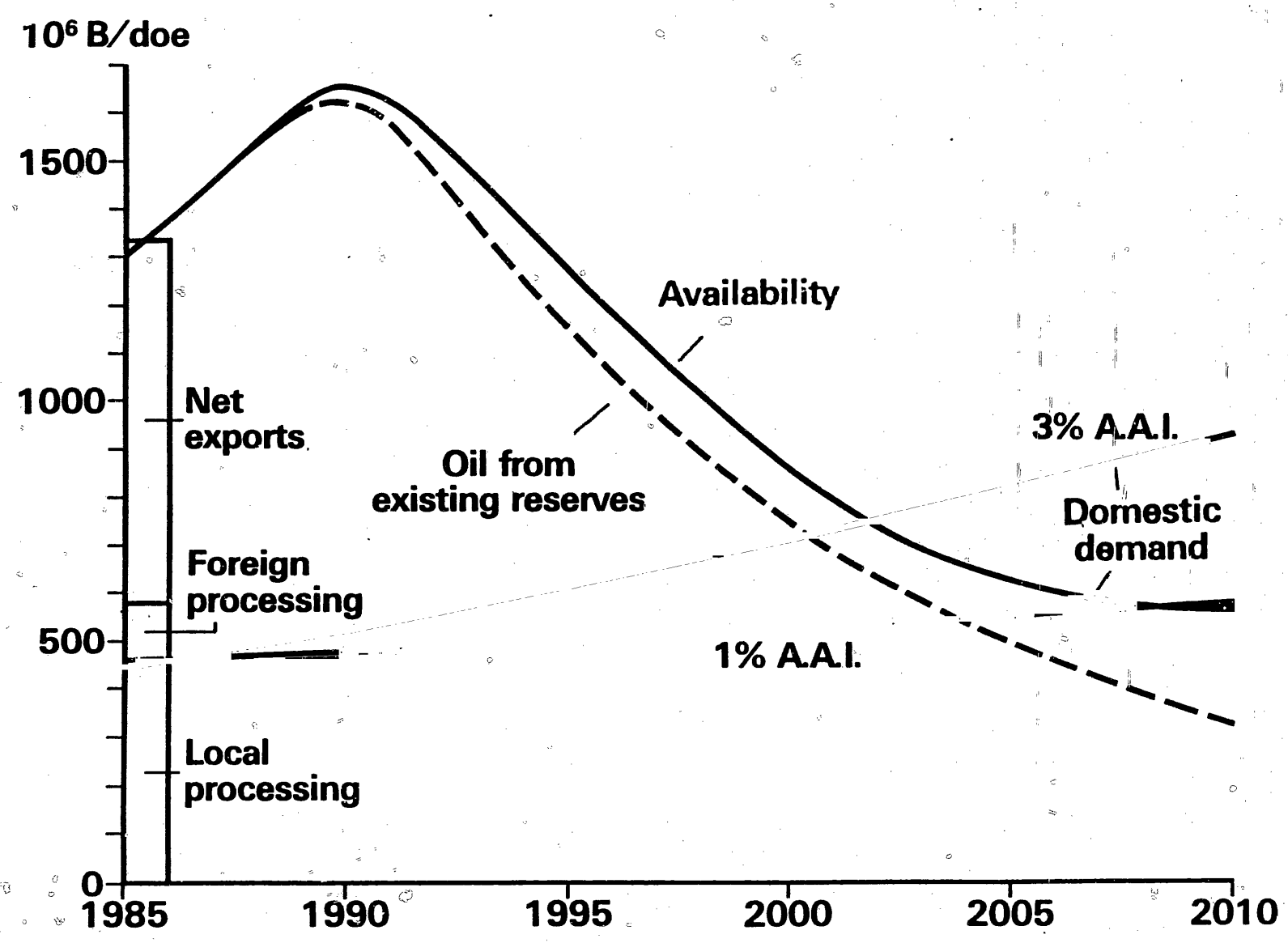


Table 8: Oil potential

Countries	Crude Oil Production ('000 mb/d)	Reserves/Production (Years left at current production)
India	656	19
China	2,740	22
Pakistan	45	10
Indonesia	1,315	17
Philippines	6	19
Thailand	37	17
Brazil	576	13
Malaysia	542	17

maintained through substantial investment in secondary recovery. By the mid-1990s production will inevitably fall to below 1 mb/d unless substantial discoveries are proven over the next few years. Although there is considerable potential, most recent oil discoveries have been of small accumulations and the general consensus is that there are unlikely to be any more giant fields. Thus, failing a higher oil price, further flexibility on production-sharing terms will need to be accepted by the government. Roughly two-thirds of crude oil production is expected and, with gas, represents nearly 60% of export earning. The government has few options other than to make the effort to maintain oil production as close as possible to present levels as long as possible.

In Malaysia, a production plateau of around 500,000 mb/d could be maintained into the early 1990s on the basis of existing discoveries, but will inevitably decline thereafter unless there are major new finds. Exploration and production conditions were eased in 1986 but there is still much uncertainty about the terms and there may need to be more dramatic changes to encourage outside investment. Although in the short term low oil prices and solidarity with OPEC may restrict production, there is little doubt that every effort will be made to keep production at the plateau level for as long as possible. If domestic oil demand can be restrained by substitution of gas, Malaysia could remain a net exporter to the end of the century.

Estimates of the size of oil reserves in China are highly speculative. Additions to reserves recorded in recent years have been substantial but are believed to have come largely from already-known reserves rather than from new fields. Despite some exaggeration, there does seem to be a fair chance of substantial new reserves from both on- and off-shore. There are also huge reservoirs of heavy oil. The increase in production from 1960 when the Chinese started developing oil on their own has been phenomenal--from 0.1 mb/doe to 2.7 mb/doe currently. This makes China the third largest producer of oil in the world. The long-term plan is to reach 4 mb/d by the end of the century which could be achieved with an annual discovery rate a little above that of the last ten years.

Historically, Pakistan has relied almost exclusively on oil imports. In recent years, however, the country has become one of the most important petroleum exploration and development areas in the eastern hemisphere. The government has recognized the need to stimulate private exploration activity through a realistic pricing formula as a vital element in its strategy for increasing domestic production. The result of the increased activity has been an exceptional increase in production of crude oil through the discovery and rapid development of new oilfields; but reserve/production ratios are still very low. Production is likely to rise to around 70,000 mb/d by the early 1990s from the current 45,000 mb/d; but Pakistan seems unlikely to be able to eliminate oil imports entirely.

Indian crude oil production has also increased dramatically in recent years, mainly as a result of the discovery and development of the Bombay High field, which contributes about 70% of current domestic production. The country still needs to import around 30% of its oil needs, a major improvement from seven years ago when it had to import 65%; so the government is actively encouraging the involvement of the private sector and has doubled the public investment program. There does appear to be considerable scope for increasing oil production from existing fields and from the discovery of new fields. Many areas with potential are still unexplored, particularly offshore where perhaps 70% of the new reserves may be found. Even with the achievement of an optimistic production potential of around 1 mb/d by 2000, up to one-half of India's oil needs may need to be imported.

In Brazil oil has long been seen as the key energy constraint, with production having been well below demand since oil was first discovered in 1940. Production has increased rapidly since the early 1980s and now supplies just over half of domestic needs. Petrobras, the state-owned company responsible for oil and gas development (amongst other activities), has built up an excellent operating record, particularly in exploration and production in the Campos Basin. It is still tightly controlled as a government executive agent responsible for carrying out the government's oil policies and is currently subject to severe labor problems and financial constraints. Present production is around 575,000 mb/d; by the mid 1990s Petrobras plans to be producing 1 mb/d and by the late 1990s, 1.5 mb/d. To reach these targets a huge amount of investment will be required which, in the light of recent drastic budget cuts and the chronic financial problems of the country, seems unlikely to be forthcoming.

Oil reserves in Thailand are very modest with condensate reserves of more importance than crude oil. Exploration activity is expected to increase in 1990 as a result of new petroleum legislation and there is some potential for increased production mainly from offshore fields. In the Philippines, the production of oil has been declining since 1983. There have been some reserve additions recently, due mainly to reappraisals, but the outlook for substantial production increases is not promising.

Hydro and geothermal: Investment in hydro has been substantial in all of the countries reviewed and there are plans extant for large power schemes in the future. Hydro has been seen as a valuable indigenous resource providing cheap electricity and other benefits for which international financing has usually been available. There is substantial untapped potential left in all the countries but, in recent years, constraints on further

development have caused the delay or abandonment of plans for their exploitation. Views have changed on the benefits of many hydro schemes--particularly large ones given their impact on the environment. The massive capital needs, the increased cost of the remaining sites and the need for international action on some projects seem likely to become even greater constraints in future.

Plans in China call for the expansion of existing capacity of 30 GW to 80 GW by the end of the century. This includes the Three Georges project of 13 GW, which involves massive movements of people and inundation of large areas of agricultural land. Cost is a major stumbling block for this and other major projects. Eventually a choice may have to be made between the development of a few major schemes and a broader application of funds over many small ones.

Despite already supplying 24% of current primary energy needs and nearly 90% of its electricity, Brazil has exploited less than 20% of the country's estimated hydro potential. Another 12% is under construction or planned over the rest of the century. The completion of these massive projects and the future exploitation of hydro resources is severely constrained financially. Environmental considerations are also beginning to play a role and emphasis has moved away from hydro in the country's plans.

In both India and Pakistan hydropower continues to provide one of the most promising avenues for development of indigenous energy resources. Potential in both countries is substantial; under 10% has been developed in Pakistan and about 13% in India. There are, however, problems with silting in Pakistan. In India the length of time needed for construction and the capital required in relation to other options has moved the focus away from hydro.

The main potential domestic source of energy in the Philippines is geothermal of which only some 11% has been utilized already. Hydro power resources are also largely untapped but their development is relatively costly due to the distance of the better sites from the grid. Some 36% of the hydro potential of Thailand has already been tapped but there is substantial additional potential in international rivers. These would require agreement mainly with Burma and Laos and seem likely to remain untapped for many years to come.

Currently, hydro contributes around 7% of Malaysia's energy needs but has the potential to increase its role significantly. However, the location of many of the untapped sources, their economics and the availability of gas make it unlikely that any major schemes will be completed in this century. In Indonesia as well, the major hydro potential lies outside the areas where the demand is located. Large-scale development of these largely unexploited resources requires the development of a substantial electricity load away from Java or the installation of undersea links between Sumatra and Java. The heavy investment cost is a perennial problem. Some geothermal power is already being used in Indonesia and there is potential for more use. Unfortunately, the economics of the various sites often compare unfavorably with other sources of electricity.

<u>Nuclear</u>: Brazil, India and Pakistan all have nuclear capacity and have plans of varying degrees of firmness to build more. However, the

programs have not been unqualified successes and their future is uncertain. There have been problems in all three countries over the efficient operation of the plants and substantial cost overruns have been commonplace.

China has two nuclear plants under construction and may be the only country in the group to continue with a substantial program through the 1990s. The Philippines has one moribund reactor and the Indonesian government has shown a fluctuating interest in nuclear development for some years. In these countries, as well as in Malaysia and Thailand, the grid and capacity needs are as yet scarcely able to absorb a nuclear plant. Nuclear has been considered a solution for the substantial generating capacity needs at the end of the century. Considerations of cost, construction delays and the need for high levels of operating expertise, and to some extent environmental worries, seem likely to deter its use from becoming of significance.

Synthetics: Investment in synthetic fuels has been considered from a variety of motives--security of supply, diversity, lower costs through new technology etc. The main constraint is the high capital cost of most of the techniques and their novelty. The Brazilian ethanol-from-sugarcane project has been an outstanding success in volumetric terms but its economic success has always been questionable. In Malaysia, a small gas to middle distillates project is going ahead and there are other minor schemes as, for example, the production of fuels from vegetable oil. However, unless there are significant cost breakthroughs or sharply increased scarcity of conventional supplies, synthetic fuels will remain largely of novelty interest.

The traditional fuels: By their nature, the volumes of traditional fuels such as firewood, crop residues, charcoal, animal waste, etc. that are consumed are difficult to ascertain. Many of the various estimates usually quoted are often incomplete and inconsistent. However, from a careful consideration of the material available within the countries reviewed it seems that traditional fuel use at present ranges from about 13% of primary energy supplies in Malaysia to around 45% in India, Pakistan and Indonesia.

In absolute terms, consumption of these fuels has been increasing although generally at a decelerating rate. They are, however, steadily lessening in importance and their share of energy supply falling.

Biomass in one form or another is China's second most important source of energy but it is a severely depleted resource. At the other end of the development scale, the majority of these fuels in Malaysia are used only for raising industrial heat and production appears to be self-sustainable. Bagasse and palm oil residues are used extensively and 75% of the heat needed for firing and drying bricks and tiles is provided by firewood and charcoal. In both the Philippines and Thailand biomass is also used extensively by industry. In Indonesia, 60% or so of the energy needs of the many cottage industries are met by charcoal and firewood. In Pakistan and India, traditional fuels are largely firewood and agricultural and animal wastes with most being used by households. In Brazil, wood accounts for a large but falling share of household use although industrial use of charcoal and bagasse is increasing.

The use of agricultural residues in industries that are largely agriculturally-based appears to be growing. In contrast, the use of

traditional fuels by households--although widespread for cooking and water heating in rural areas of all the countries--is generally declining. The extent of the drift to commercial fuels varies considerably, depending on income and the degree of sophistication of the distribution network. In some parts of China and Indonesia, where subsistence economies prevail, the availability and collection system for traditional fuels is often more reliable than that for oil products. In Malaysia, by contrast, the use of wood is largely confined to certain small rural areas, although charcoal continues to be used in towns for cooking some traditional dishes. It is becoming increasingly difficult for traditional fuels to compete with commercial fuels against a background of rising incomes, even though their prices are often only about 60% that of kerosene. Oil products are usually more convenient to obtain and use and in practice can cost less when heat efficiency is taken into account. Thus, Malaysia is probably near the point where consumption per head of traditional fuels will stabilize and the use of traditional fuels will be largely confined to agriculturally-based industries. Urbanization, modern industrial activity and motorized transport are all reducing the role of traditional fuels as the countries' incomes increase. For example, in the early 1960s when income per capita in Thailand was less than $350, 90% of urban households used traditional fuels. Now, with per capita income about $800, the proportion is less than 30% with most having been replaced by LPG and electricity.

The potential demand for commercial fuels to replace traditional fuels can be overstated. Generally, for example, one boe of LPG can replace four boe of firewood. Nonetheless, they do represent a source of upward pressure on commercial supplies; for example, to replace current levels of traditional fuel in China would probably need about 1 mb/doe of commercial fuels.

A great deal of research and field testing of new technology for the more effective use of traditional fuels has taken place. The production of biogas from collectible cattle waste in biodigesters, the production of ethanol and methanol or the use of vegetable oils as transport fuels have made only very modest headway, however. There has also been some effort to introduce more efficient methods of cooking by traditional fuels. It is clear, however, that oil, gas and electricity are preferred as soon as they are readily available and affordable.

Traditional fuels will continue to play a major role in some industries in all the countries reviewed because of their availability and the impossibility of other fuels competing solely on a heat basis. Future growth will be fairly modest in line with the reduced role of many of the agriculturally-based industries and because of the introduction of more efficient machinery. But this growth seems unlikely to be enough to offset the impact of rising incomes and the desire for modernity on use in households and non-agricultural industries. In all countries, the total volume of traditional fuels in use at the turn of the century seems unlikely to be much higher than now and could well be a great deal less in a number of them. Thus, their significance will become marginal in most of the countries.

IV. ENERGY PRICING POLICIES: THE KEY TO FUEL SUBSTITUTION

The prices of all major fuels--electricity, gas, coal and petroleum products--are regulated in all eight countries through taxation and subsidy policies. Energy pricing policies differ between the oil-exporting and oil-importing countries. In India, Brazil, the Philippines, Thailand and Pakistan, taxes are higher than in Indonesia and Malaysia (which are oil exporters). Taxes and duties on premium gasoline in the former group of countries are in excess of 50%. Taxes on petroleum products, accounting for a large portion of government revenues, are generally discriminatory in nature, with the largest burden placed upon the users of gasoline (who are the more financially-secure section of the population). On the other hand, LPG or kerosene (used mainly as household fuels) and diesel carry either low taxes or are subsidized. In general, the taxes on the most substitutable products appear to be uniform. Fuel oil is exempt from taxes largely because it is an intermediate product used for power generation and manufacturing. This system of discriminatory pricing is consistent with the governments' demand management policies which are designed to discourage the use of luxury fuel products.

In recent years energy prices in several developing countries have been aligned to reflect the prices on the international markets. This marked a significant change from earlier policies which restricted the pass-through of international prices to domestic prices in an effort to insulate the internal prices from external shocks.

In Pakistan, for example, the weighted average price of petroleum products increased sharply (by 49%) between 1980 and 1985 in line with the increase in world oil prices. This was a result of a shift away from the government's previous policy of softening the impact of international oil price increases on domestic consumers, which had placed too big a burden on government finances. In an effort to alleviate the pressure of the growing demand for natural gas, which is in short supply, and to economize its use of competing fuel oil, price increases for fuel oil have been restrained in Pakistan. Gas prices have risen substantially, bringing gas prices to two-thirds of parity with fuel oil prices. However, the decline in world oil prices in 1986 raised the relative price of gas to about 21% higher than the fuel oil price. In general, in the other countries where natural gas is significant, there also appears to be a move towards pricing gas closer to parity with oil products.

Although domestic product prices in Malaysia are now closely aligned to world prices--largely represented by Singapore postings--(facilitated by the automatic pricing mechanism adopted in April 1983), the government still exercises some pricing control. The removal of heavy subsidies on diesel and kerosene in 1984, in pursuance of the "four-fuel" policy, resulted in large price increases. The sharp decline in world oil prices and refinery prices of products in 1986 was countered by substantial tax increases on petroleum products. Taxes on premium gasoline and auto diesel now are about 42% and 9%, respectively, of the retail price, while there are no taxes and duties on industrial fuel oil. Despite its low import price, coal has not been able to penetrate industries where gas is available. Coal also appears an unlikely

alternative for the power sector, where fuel oil is tax exempt and gas is competitively-priced. The pricing of natural gas vis-a-vis other fuels is crucial in establishing its market competitiveness in furtherance of the "four-fuels" policy. At present kerosene is cheaper than gas for domestic use and fuel oil is the cheapest form of commercial energy.

In an effort to correct distortions in domestic prices in Indonesia, petroleum product prices were increased substantially between 1981 and 1985. However, in 1986, automotive diesel oil prices were reduced by 13% while those of industrial diesel oil and fuel oil prices were reduced by 9%. In order to encourage movement away from kerosene and towards LPG in the residential sector, the government also reduced the price of LPG. However, the prices of kerosene and diesel are still substantially below international prices, which continues to discourage the necessary substitution of these products and encourages market distortions and misuse.

Like most of the other developing countries, India's energy pricing policy makes a distinction between sources that are intermediate inputs to the industrial sector or essential to consumers, and those that are non-essential or "luxury" fuels. While the pricing of crude oil, oil products, natural gas and coal are centralized, the prices of traditional and non-conventional fuels are determined in the market place. State governments play an important role in determining the prices of commercial fuels. The conflicts between the central and state governments, however, have led to substantial delays in adjusting prices in response to market conditions as well as national goals. The main objective of Indian pricing policy is to curtail the growth in oil consumption in an effort to reduce the negative balance of payment effect of high oil import costs. Gasoline is the most heavily taxed product and the high price at the pump (to end-users) reflects a series of added charges. On the other hand kerosene is heavily subsidized; however, its use is also rationed by means of allocations to the various states as well as through ad hoc quota systems. This differential tax treatment provides the main vehicle for cross-subsidizing oil products.

In China, prices for most forms of energy are kept artificially low, which makes it difficult to justify new investment and does little to encourage conservation. Gasoline and kerosene are subsidized, with differential price systems operating between the enterprise regions and elsewhere. Coal, which is expected to bear the burden of the country's future growth, is usually not able to command a price sufficient to justify its transportation over significant distances. The advent of the new State Coal Corporation, with responsibility for its profitable operation, should put upward pressure on prices but wide-ranging and bold price reforms remain vital if new investment is to take place.

In the Philippines, most fuels are taxed. Gasoline receives discriminatory treatment, reflected in substantially higher taxes than other petroleum products. Taxes on LPG or cooking gas and kerosene are relatively low since they are used mainly as household fuels. Diesel used in mass transit systems carries lower taxes than for individual use, while fuel oil is exempt from ad valorem tax largely because it is an intermediate product used for power generation, manufacturing and large marine vessels. The Philippines, like other developing countries, has sought to isolate domestic oil prices from external shocks. The Oil Price Stabilization Fund (OPSF) was

established on October 10, 1984 with the objective of smoothing out fluctuations in international oil prices. In an effort to protect the domestic coal sector from sharply declining international coal prices (compared with 1981, international coal prices in 1988 were less than half in real terms), imported coal has been taxed very heavily. Taxes and tariffs added more than 30% to its price, and more than a 50% premium was paid to domestic coal producers in 1988 to enable them to cover costs. However, this policy has been changed significantly. The new pricing policy gives consumers the option of using domestic or imported coal. Thus, the extent of protection is limited to the import duty.

In Brazil, gasoline is also the most heavily taxed product, primarily to curtail oil use and to subsidize the other oil products and alcohol. The price of alcohol had been pegged at 30-40% below gasoline in order to encourage purchase of alcohol cars; the differential has now been reduced to around 25%. Due to the decline in the international price of oil, the subsidy on alcohol has proved extremely costly. Subsidies to the alcohol program, administered through PetroBras, were costing the company $37 million per month in early 1988. To lessen the demand for oil, the government now plans to encourage natural gas. Taxes on products such as diesel and fuel oil--used for freight transport and industrial production--and LPG are relatively low. LPG prices have been reduced since 1985, mainly to encourage its use in rural households as a replacement for wood and charcoal.

Developing countries face a dilemma with regard to electricity and gas pricing. While on the one hand there is a need for gas and electricity rates to reflect their true costs, on the other hand the higher prices resulting from providing additional capacity are likely to cause social and political problems. In Brazil, for example, in an effort to facilitate substitution away from oil use in the industrial and residential markets, electricity has been priced below both its historic cost and long-run marginal cost (LRMC). Moreover, electricity prices are uniform in all areas of Brazil, despite the large differences in transmission and distribution costs. In Pakistan, the electricity tariff rates of the Water and Power Development Authority (WAPDA) were about 30% below LRMC estimates in 1986. Average electricity revenue in China is also only 60-70% of marginal supply costs. In Indonesia, difficulties in calculating the LRMC for natural gas, due to production-sharing contracts, has made its institution impractical.

Tariffs that reflect the costs of different grids and different load factors and other technical characteristics are being proposed in a number of countries. There are also efforts to differentiate demand charges by time of day, i.e., peak and off-peak pricing. For example, a new tariff structure is now being constructed in Thailand which is anticipated to shift demand away from the peak to the off-peak period. In Pakistan, efforts are being made to change the electricity tariff rates to reflect the time costs of increasing capacity and this seems likely to be the pattern for the future.

V. CHANGING ATTITUDES TOWARDS THE ENVIRONMENT

Until very recently, the damage caused to the environment in providing and using energy was scarcely taken into consideration by the policy makers in the eight countries. The need to provide energy for economic development was overwhelming and, in any case, the volumes involved generally appeared small in relation to the environment.

This is not to say that an awareness of the pollution caused by energy use has only just come to the fore. It has been quite clear for years that, for example, the appalling smog caused by coal burning in Chinese cities or the severe traffic congestion and fumes in Jakarta are unhealthy. However, pollution was and generally still is widely accepted as an unfortunate but necessary byproduct of economic progress.

The higher level of awareness and action to safeguard the environment in industrial countries has only recently begun to influence views in the countries reviewed. The last two or three years have seen the emphasis on global energy issues in industrial countries moving on from land degradation and deforestation to global warming. Attempts to focus these issues on developing countries' behavior have aroused strong feelings, particularly in Brazil, and charges of meddling and neo-colonialism. Nonetheless, attitudes are changing towards the destruction of tropical forests for use, amongst other things, in the supply of fuelwood and charcoal to industry. The change comes partly from public pressure both from within and without and a realization that it is not necessarily an economically-sound route. In addition, international and national activists are now more able, and likely, to exert pressure on international lending institutions involved in the financing of energy projects. This has been particularly noticeable in Brazil over large-scale hydro projects and forest exploitation.

Global warming is perhaps the major environmental issue that cuts across international boundaries but it is not clear how it will affect future energy use in the countries reviewed. The extensive use of coal in China and India, particularly its direct burning in an unwashed state, is a major contributor to CO_2 levels. However, China and India have no alternative but to increase the use of coal. China is now the world's largest coal producer and its domestic use is expected to at least double by the end of the century. Where the OECD countries may be able to help most is in the transfer of technology to enable the coal to be cleaned before use and to be burnt more efficiently and cleanly. In the other countries, coal is not a major contributor to energy needs. Their plans for greater coal use are being emphasized less than a few years ago; although not because of environmental pressure. The movement to natural gas, the clean-burning fossil fuel with the least likely impact on global warming, as compared say with oil and coal, has already begun--largely on economic grounds. International agreements on the environment are unlikely to have a significant accelerating effect on this trend although they could encourage gas exports. The most significant effect is likely to be from the transfer of more energy-efficient equipment to developing countries. Preliminary estimates indicate that the marginal costs of reducing a ton of CO_2 (especially beyond preliminary 10-20% reductions) far exceeds the cost of saving a ton of high CO_2-emitting energy sources such as coal through efficiency improvements or substitution. This should mean the

encouragement of faster substitution by natural gas, electricity and LPG through the price mechanism.

In a few of the countries reviewed, nuclear power development plans do seem to have been affected by the global revulsion against nuclear power. The impact has largely been indirect, through steeply-increased costs of construction and operation, although local anti-nuclear feeling in, for example, the Philippines has been encouraged by outside views.

One of the earliest environmental issues to be tackled in a number of the countries is that of land degradation, from extensive use for fuel of wood and animal waste. Where this is already a serious problem, in India, Pakistan, China and Brazil, attempts have been made to remedy the situation. Replanting of fast-growing tree species has been encouraged and new, more efficient ways of using traditional fuels introduced. There has been little record of success, however, despite the involvement of various international bodies. Higher incomes, enabling the bulk of the population to purchase commercial fuels, is probably the only lasting solution.

Urban pollution from traffic fumes and the inefficient burning of dirty fuels in households and industries is also beginning to arouse local protests. The retention of sulfur, nitrous oxide ash and poor combustion generally take a heavy toll in terms of air pollution and health in large cities such as Jakarta, Calcutta and Beijing. Although still largely tolerated, the effect on health in economic terms must eventually force measures to be taken to improve the worst situations.

Large-scale hydro schemes have always met some protests on environmental grounds but objections to projects have increased in recent years. Many of the potential sites in the countries reviewed involve more complex geo-technical factors than before. The less beneficial side to hydro development for soil fertility, fisheries and cultures is being taken into account in the planning process in a number of the countries. In China, for example, the Three Gorges project will displace some half a million people and submerge ten towns and 44,000 hectares of good agricultural land. This impact and the damage to tourist sites has contributed a little to delays in constructing the project, although funding difficulties have had the most impact. The same has been true in Brazil and Malaysia, although in the former, funding problems have been exacerbated by international pressure from environmentalists.

Generally, global and local environmental concerns will lead to some acceleration of an on-going substitution process in the eight countries, except perhaps in China. The move to gas will be further encouraged at the expense of coal, large hydro schemes further postponed, traffic control systems introduced in some large cities and more fuel-efficient equipment introduced.

There is considerable scope for saving energy without restricting economic growth in all the countries reviewed. Most savings will come about through conventional technological development and transfer. Perhaps 10-20% of energy could be saved at costs which are economic in relation to the energy that might otherwise have been used. However, the deeper the savings, the greater the cost and it is unlikely that there will be many efficiency improvements in the countries reviewed solely on environmental grounds.

VI. SCENARIOS FOR ENERGY USE INTO THE NEXT CENTURY

This study of energy development in the eight countries has concentrated on the major driving forces involved. Based on our analysis of these forces and their projection we have made an assessment for each country of their future demand for energy to the year 2010.

We have used two methods in parallel in arriving at a view of the future; one was a "ground up", sector-by-sector analysis, the other used the econometric demand models constructed for each of these countries. 1/ There is a significant level of consistency in the projections from the two methods in the short to medium term but there is divergence in the projections from the late 1990s onwards. Projections for each country in terms of market and primary energy demand are shown in Appendix I.

The projections of demand take into account forecasts of (i) economic growth, (ii) the changing relationships between economic growth and energy demand, (iii) structural changes, and (iv) the potential for substitution between fuels at different price levels. The evaluation of these elements has been based on sectoral analysis of demand for energy in the key markets, within the context of investment plans and energy policies in the various countries. For example, it has been assumed that oil-importing countries will allow only a partial pass-through of any decline in oil prices to end users to encourage savings and substitution by indigenous fuels.

In the past, the role of energy conservation has been somewhat limited in developing countries. However, the need for greater efficiency is being increasingly recognized by governments in all the countries reviewed. It is expected that these attitudes will be supported by a higher rate of technological transfer than in the past and also be encouraged in some countries by local and global environmental pressures. As a result, it is anticipated that energy intensities will fall over much of the period. This is the major point of divergence between the analytical approach and the model-based approach. The models which show increasing intensities are geared to past behavior and a faster rate of substitution or of technological transfer has not been incorporated (Figures 12A and 12B). 2/ It is thus very much a "business as usual" scenario, resulting in a projection of energy demand in 2010 of some 15 mb/doe higher than obtained by the analytical approach. The purpose of this approach was to illustrate the higher level of energy consumption that is likely to occur if the trends of the 1990s are allowed to continue into the next century.

The projections represent a "most likely" case for the eight countries related to the economic outlook expressed in the latest World Bank projections of global economic activity. It is clear that each country is unique but the eight represent 50% of total developing country energy demand, and, as such, can be considered a guide to overall trends.

1/ The specification of these models is described in Appendix II.
2/ Figure 12A includes China while Figure 12B does not.

FIG 12A INTENSITY OF ENERGY USE, THE 'EIGHT'

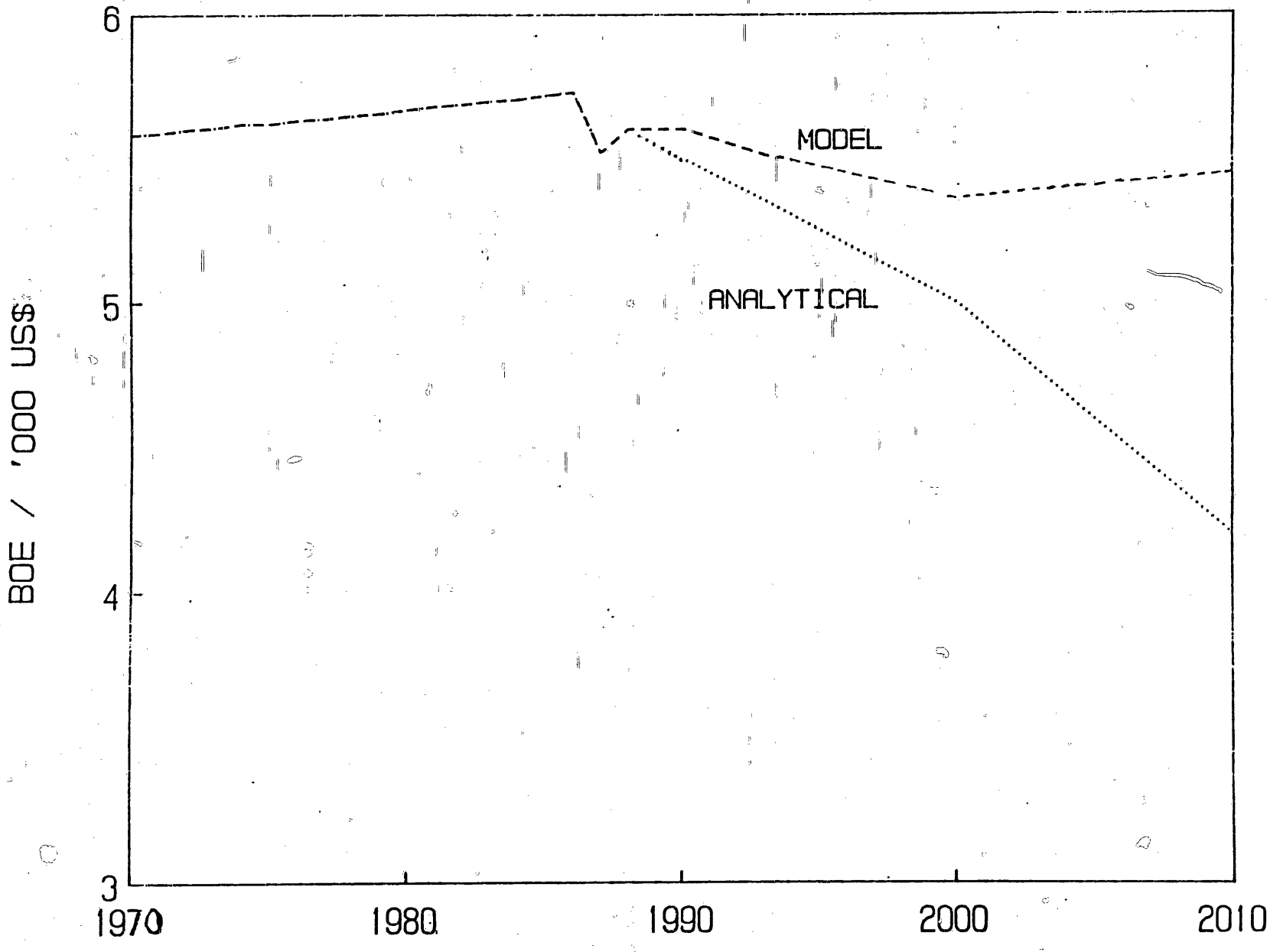
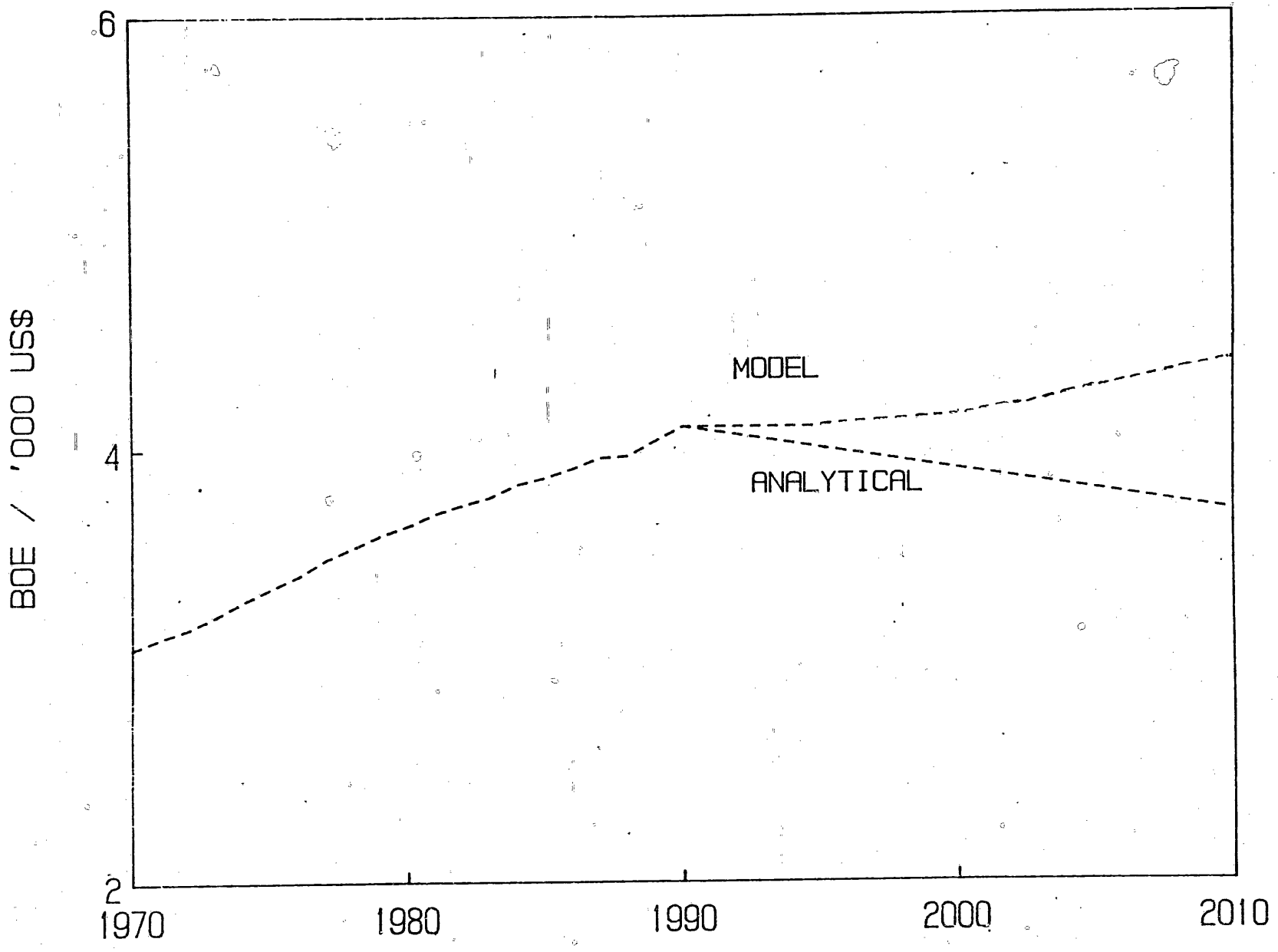


FIG 12B INTENSITY OF ENERGY USE, THE 'SEVEN'



A. Economic Assumptions

Forecasts of GDP growth for each country, the key macro-economic variable, and of international oil prices form the basis for the energy demand forecasts. For developing countries as a whole the World Bank's base-line forecast suggests that economic growth will accelerate in the 1990s but will not reach the high levels achieved in the late 1960s and early 1970s (Table 9). The high economic growth rates achieved by China and Pakistan in the 1980s are not expected to be maintained in the forecast period, while growth in India is projected to remain more or less stable at the rates of the past decade. Economic growth in the Philippines is expected to recover from the stagnation of the 1980s; and in the remaining countries' growth will be significantly higher than in the recent past. Beyond the turn of the century, slightly lower growth has generally been assumed. The oil price scenario adopted envisages weakening international oil prices (in real terms) in the short term due to a slow down in economic growth and higher inflation in the OECD countries. Other key factors contributing to the lower short-term oil price outlook include increases in production capacity of some OPEC members such as Iran and Iraq, and lack of consensus within OPEC on the distribution of higher quotas. Given an assumption of steady growth in global oil demand and declining oil production in the industrial countries, oil prices are expected to trend upwards in the 1990s, however. Sharper increases are anticipated in the late 1990s due to a further tightening of the international oil market as exports from non-OPEC countries decline. Prices are assumed to remain constant in real terms in the next century at the levels reached in 2000 as factors such as new discoveries, technological developments and the development of alternatives to oil prevent prices increasing further.

B. Future Market Structure

At present the industrial sector takes the largest share of commercial energy in end-use markets in all countries, except Malaysia and Thailand where transport dominates (Figures 13A and 13B). We expect the growth of heavy industry to continue through the 1990s in the lower-income countries of the "eight." Industrial expansion will be based on the latest technologies and, with the greater use of gas and electricity, energy efficiency will be improved significantly and at a faster rate than in the past. In the more advanced countries the emphasis on low-cost export and higher technology industries will change industry structure in favor of less energy-intensive manufacturing. The heavy weight of China, which will be building up its heavy industry based on coal well into the next century, will ensure that industry in the total of the eight countries will remain the largest consumer of end-use energy in 2010. However, excluding China, transport will be taking the largest share of end use energy by 2010.

In a high-growth and generally economically-successful environment, we expect the desire for personal mobility and increased trade in goods to be reflected in a continued rapid increase in road transport. On the basis of the economic growth envisaged, the number of vehicles per thousand people could nearly quadruple over the next 20 years. Fuel consumption will not rise as fast, however. Much of the increase in vehicle numbers outside of Brazil will be in motorcycles which have low fuel consumption. However, in China and India particularly, we expect the truck population to rise rapidly to support industrialization and compensate for the inadequacies of the railways. Car

Table 9: International Oil Price and Economic Growth Assumptions

	1988	1989	1990	1995	2000	2010
International Oil Prices						
Current a/	13.6	16.2	16.4	22.0	33.7	48.4
Constant (1985)	9.9	11.8	11.3	12.0	15.3	15.3

GDP Growth Assumptions
(% p.a.)

	1980-88	1988-95	1995-2000	2000-2010
All Developing Countries b/	4.1	4.6	5.5	5.1

Source: World Bank (IEC).

a/ OPEC average price, weighed by export shares.
b/ Specific growth rates were used for each country in the sample.

FIG 13A MARKET DEMAND FOR COMMERCIAL ENERGY

IN THE 'EIGHT'

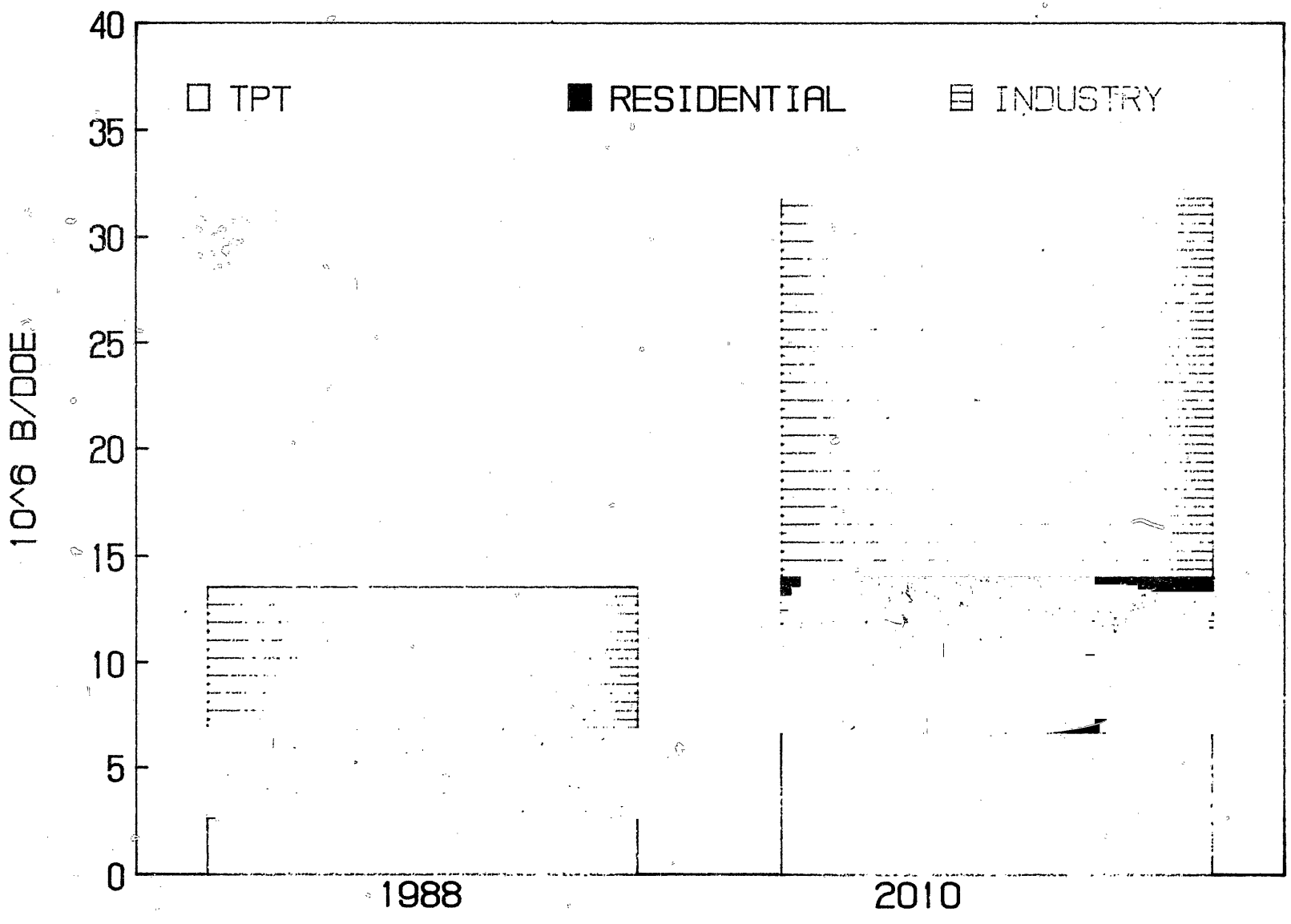
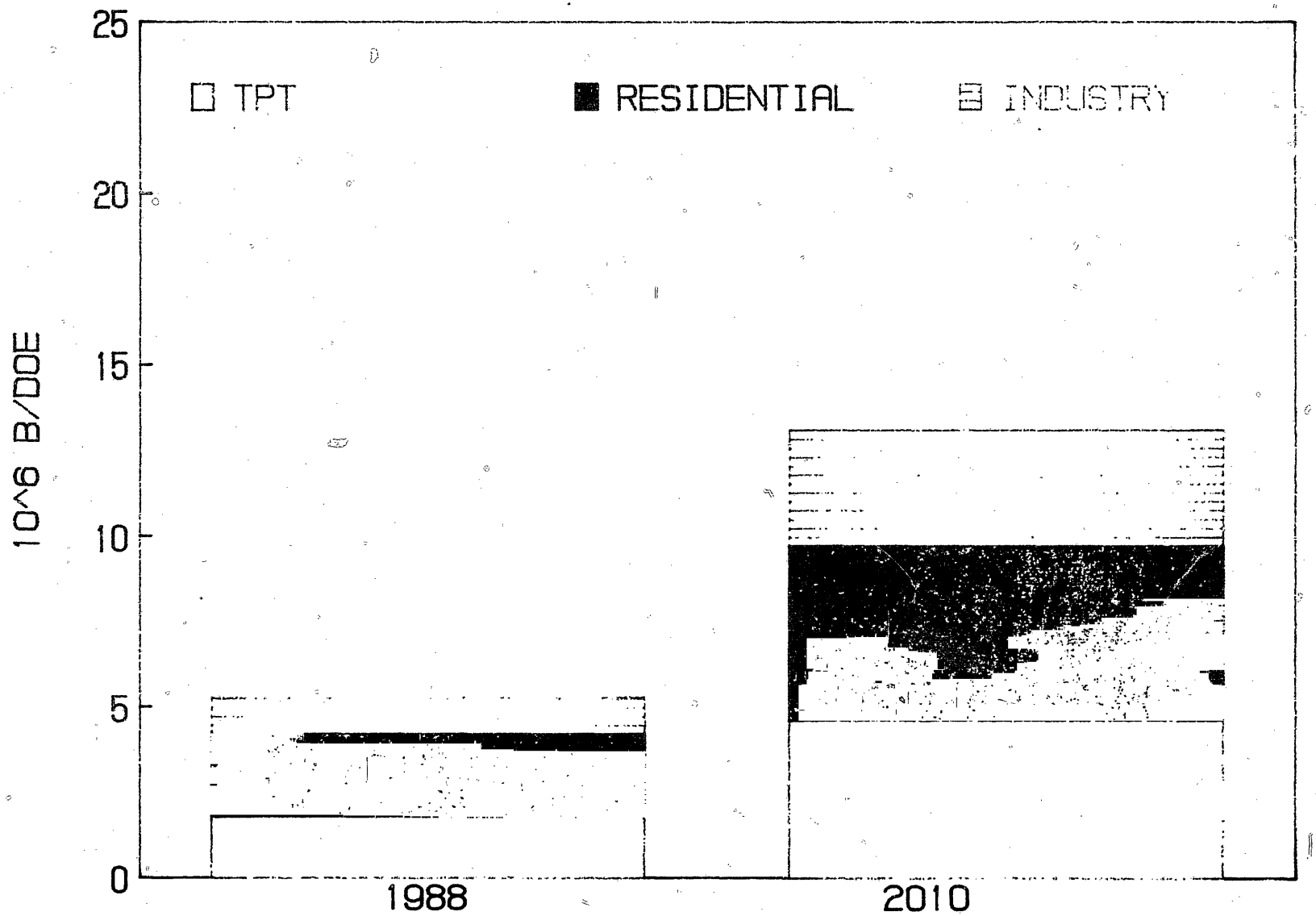


FIG 13B MARKET DEMAND FOR COMMERCIAL ENERGY

IN THE 'SEVEN'



and truck fuel efficiencies will continue to improve substantially in all the countries. Technological transfer and diffusion will grow more rapidly than in the past, particularly as car manufacture becomes more globalized--thus helping to bring efficiencies closer to those of the OECD countries. Traffic congestion may temper some of the expected efficiency savings in major cities such as Beijing and Jakarta but, in general, rapid motorization will be countered by very substantial efficiency improvements. Air travel will also expand much faster than GDP growth but the introduction of more efficient aircraft and operations will moderate aviation fuel needs. The conversion of Indian and eventually Chinese railways to diesel and electricity will result in energy for rail traffic barely increasing. In all eight countries, transport will remain the largest single market for oil products if not also the fastest-growing.

The increase in per capita incomes projected and the continued spread of urbanization will reduce the share of traditional fuels used by households. We expect that the historical transition from traditional fuels to kerosene and to LPG and electricity will accelerate, perhaps largely missing out the kerosene step in some urban areas. By the end of the 1990s many major rural electrification schemes will have been completed in most countries and LPG distribution systems will be more widespread and reliable. In addition, there will be greater use of natural gas by households in a number of countries, including perhaps China. We have assumed that the intense local, as well as global, pollution caused by the present reliance on coal in China for household and business space heating will start to be seriously tackled only by the late 1990s.

This steady substitution of more efficient fuels for household use in all eight countries and the reduction in price subsidies will help to keep consumption per household down despite rapid growth in electrical appliances. Intensity of energy use for services seems likely to fall significantly as electricity is substituted for oil fuels and more efficient equipment is installed. Nonetheless, the inexorable growth of population, household formation and urbanization will continue to mean substantial energy growth in the household and services markets. Generally, it will be at a slightly lower rate than income.

C. Electricity Generation

From the analysis of end-use energy demand and substitution, we expect demand for electricity to grow faster than GDP. There will be successful attempts to reduce the present high level of transmission and distribution losses. The expansion of grid systems, the installation of modern generating capacity and better management overall will also help to moderate the growth of generating capacity and fuel input. Nonetheless, electricity generation will represent the largest single consumer of primary energy in all eight countries by the late 1990s. As the need for generating capacity grows the availability of indigenous resources will have a larger influence on fuel choice. Coal and hydro will make up the bulk of the incremental capacity in China and India (we have not assumed a significant impact from international initiatives on global warming). In almost all of the other countries there are substantial hydro resources unexploited and we have assumed that, despite some misgivings on their environmental impact and initial cost, some will be developed. In Brazil, Indonesia, Malaysia, Pakistan

and Thailand gas will be used as it becomes available for its low initial costs, ease of operation, efficiency and, to a lesser degree, its cleanliness. In Pakistan, the well-developed gas transmission network will retain its importance; however, supply constraints may moderate its growth. In the medium term, some countries will have recourse to additional use of oil-fired capacity but even a major oil exporter like Indonesia will be unable to use oil for the substantial capacity increments needed.

D. The Future Pattern of Fuel Use

As a result of the structural changes and substitution brought about by pricing policy changes, the pattern of fuel use will change over the forecast period (Figures 14A and 14B, and Table 10). Oil at present accounts for some 38% of total primary energy demand in the countries reviewed, if China is excluded. The inclusion of China reduces oil's share to 27% and makes coal the main source of primary commercial energy with a share of 55%. Over the next 20 years, as motorization increases and other fuels become available, coal's share should fall in all countries where it is presently used. By the year 2010, its share of total primary energy for all countries is expected to fall to 45% (excluding China, to 27%). Use in volumetric terms should double, largely through increased use for electricity generation. All countries should show some increase in coal use, although outside of China and India it will be very modest.

Hydro use should more than double, with substantial growth in China and India. Nuclear use should remain insignificant, with only four of the eight countries building new plant and no major revival of interest.

All the countries reviewed, except perhaps the Philippines, have major resources of gas. Gas should become the favored fuel and increase its share of primary energy from 5% at present to 15% by 2010. It should penetrate all markets, even transport in a small way; but its main growth will be in industry and in electricity generation.

In general, the more exotic alternatives such as photovoltaics should have little impact, largely on cost and technical grounds, but could be of local significance in some areas.

E. Changes in Oil Consumption

The need to preserve indigenous oil for export in the three oil-exporting countries and guard against balance of payments problems in the importers should mean a heightening of present attempts to reduce oil consumption. Oil's share in primary energy is expected to fall but consumption seems likely to continue to increase through to 2010, even under optimistic assumptions about savings and substitution--largely as a result of increasing motorization and switching out of traditional fuel in the residential sector. Under this scenario, oil consumption seems likely to double in these countries by the 2010. Alternatively, however, assuming business as usual (modest energy conservation and substitution) oil consumption could triple by 2010. As a result of rapid energy consumption growth and on the basis of the developments in the oil supply picture it is anticipated that the import requirements in the five oil-importing countries

FIG 14A COMMERCIAL PRIMARY ENERGY IN THE 'EIGHT'

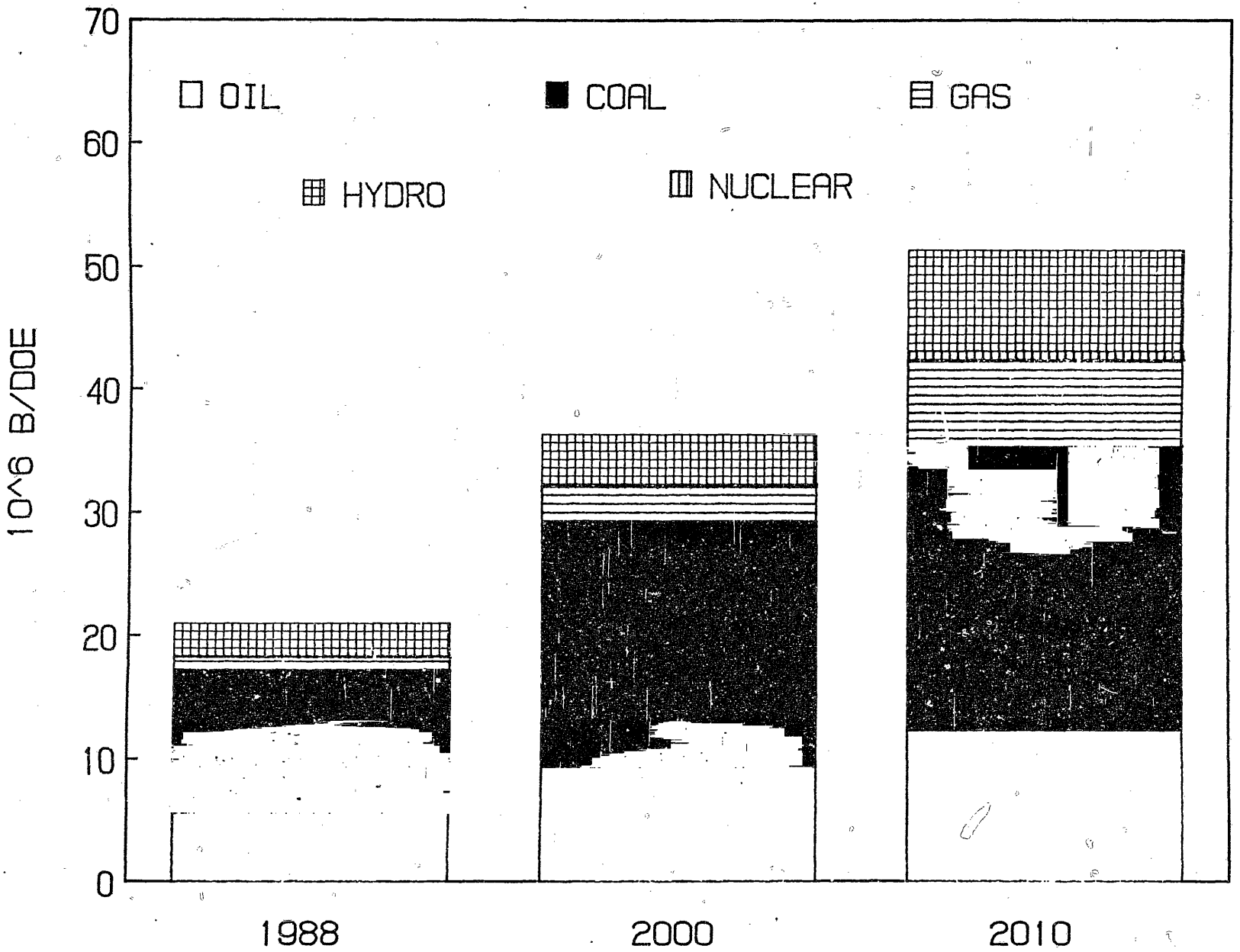


FIG 14B COMMERCIAL PRIMARY ENERGY IN THE 'SEVEN'

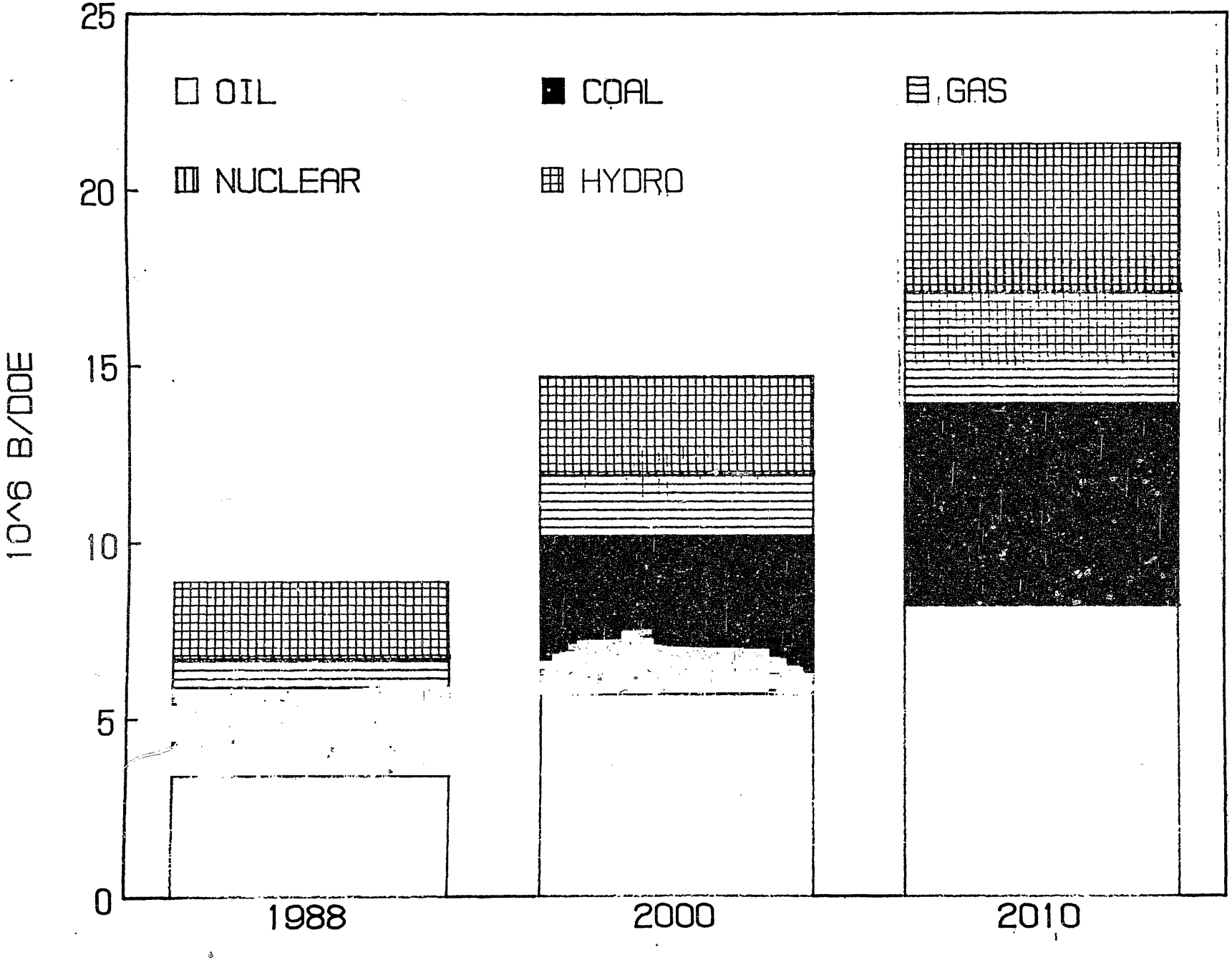


Table 10: Commercial Primary Energy Consumption Forecast

In the "Eight"

	1988		2000		2010	
	MBDOE	%	MBDOE	%	MBDOE	%
Oil	5.6	26.6	9.3	25.6	12.3	24.0
Coal	11.6	55.2	20.0	55.1	23.0	44.8
Gas	1.0	4.8	2.7	7.4	7.1	13.8
Nuclear	0.1	0.5	0.2	0.6	0.7	1.4
Hydro (etc.)	2.7	12.9	4.1	11.3	8.2	16.0
Total	21.0	100.0	36.3	100.0	51.3	100.0

In the "Seven" (excluding China)

	1988		2000		2010	
	MBDOE	%	MBDOE	%	MBDOE	%
Oil	3.4	38.2	5.7	38.8	8.2	38.5
Coal	2.5	28.1	4.5	30.6	5.7	26.8
Gas	0.8	9.0	1.7	11.6	3.2	15.0
Nuclear	0.1	1.1	0.1	0.7	0.2	0.9
Hydro (etc.)	2.1	23.6	2.7	18.4	4.0	18.8
Total	8.9	100.0	14.7	100.0	21.3	100.0

will be 65% and 88% of total oil needs in 2000 and 2010, respectively, compared with about 45% in 1988 (Figures 15A and 15B). The import dependence of Brazil and India (the two largest oil-consuming countries) is expected to increase rapidly over the forecast period. Currently, about 48% and 31%, respectively, of Brazil's and India's oil needs are met through imports (see Table 11). It is anticipated that Brazil's oil import dependence will grow to 50% by 2000 and to 81% by 2000. India's import requirements are expected to increase to 64% in 2000 and to around 90% in 2010.

Due to strong growth in oil consumption and rapidly depleting oil reserves, it is anticipated that the three oil-exporting countries in the sample could become oil importers by 2010. This group's oil import needs are estimated to rise to around 45%. Malaysia and Indonesia may manage to remain net exporters through the 1990s and perhaps beyond. Based upon the low oil supply prospects in China, it seems likely that China will become a net importer of oil by the late 1990s. Under optimistic oil supply prospects and an assumption of slower growth in demand, Indonesia may be able to preserve its role as an oil exporter; however, its exports could decline from the current level of 64% of its output to around 11% even under this scenario. The potential squeeze on oil exports from domestic demand in the oil-exporting countries and the rapidly increasing dependence on imports of the others makes it clear that future energy policies have little choice than to encourage greater exploration for hydrocarbons and the development of a broader range of energy resources.

By 2010, transport fuels will account for 49% of the total oil demand of the eight countries (Figures 16A and 16B), compared with 41% at present. Most of the remaining growth will be in household use, with some additional growth in fuel oil and diesel for electricity generation over the medium term.

The gasoline cut of the demand barrel will increase in relation to middle distillates with expanding private motorization and the greater use of gas and LPG in industry and households.

F. The Intensity of Energy Use

As mentioned earlier, in the developing countries the intensity of commercial primary energy use in relation to GDP has increased over the last two decades (in contrast to the OECD countries where it has fallen). From our analysis of the past and from the results of our baseline analytical forecasting process, we do not expect this trend to continue in the countries studied.

The results indicate that energy intensity will continue to increase through the early 1990s in some of the poorer countries such as Indonesia and India. However, over the full period, and particularly from the late 1990s, the results from the sector-by-sector analysis indicate that intensities will fall in all the countries reviewed (Figure 17). Structural change, a faster rate of technological transfer, and fuel substitution all have roles in this process as described in the earlier chapters. The impact of these elements on energy demand is illustrated by the difference between the results from the analytical projections which take into account significant future changes in energy efficiency and fuel substitution and those from the oil model which assumes business as usual.

FIG 15A POTENTIAL OIL IMPORT GAP (HIGH)

IN OIL IMPORTING LDC'S

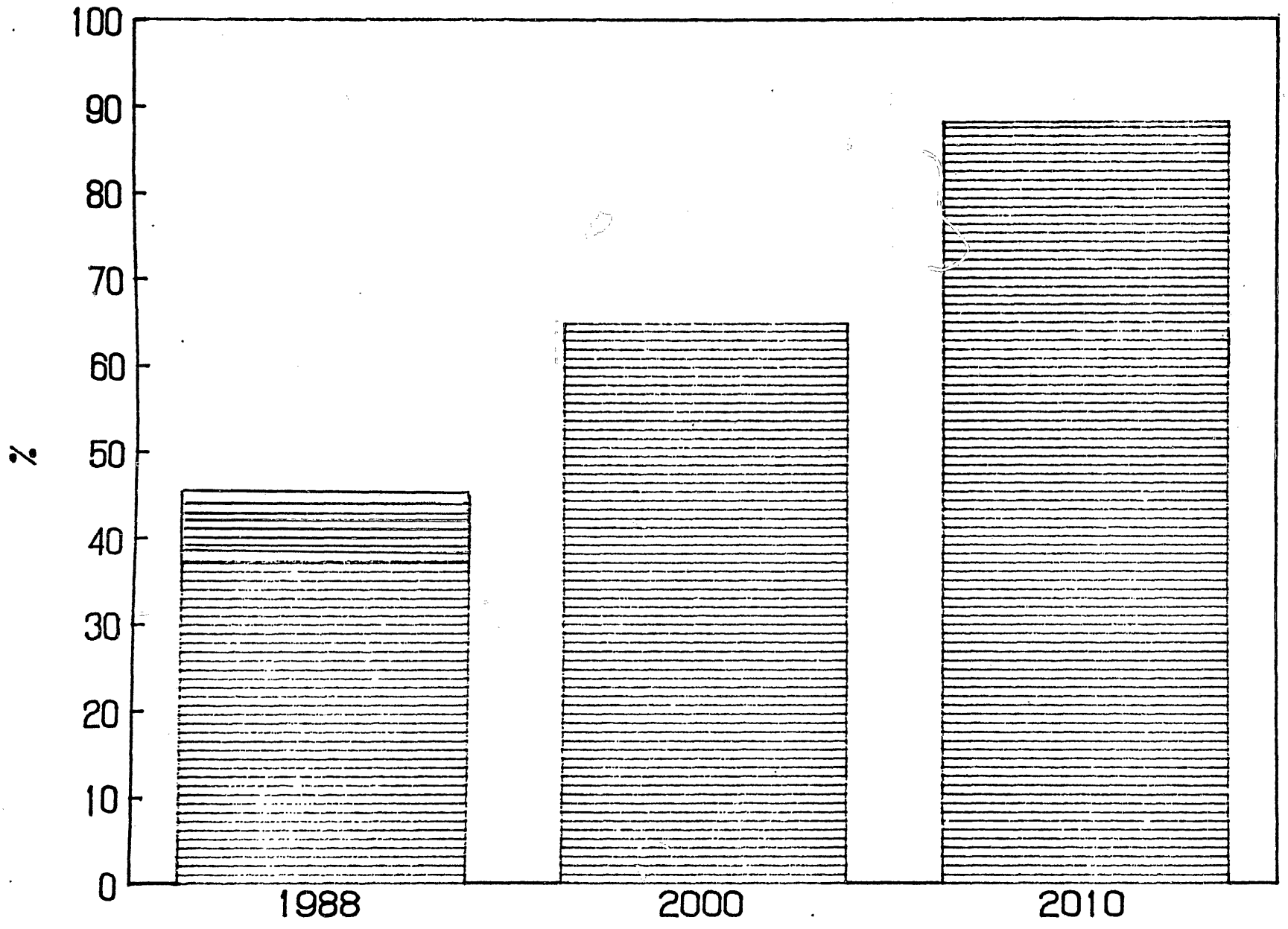


FIG 15B POTENTIAL OIL EXPORTS

IN OIL EXPORTING LDC'S

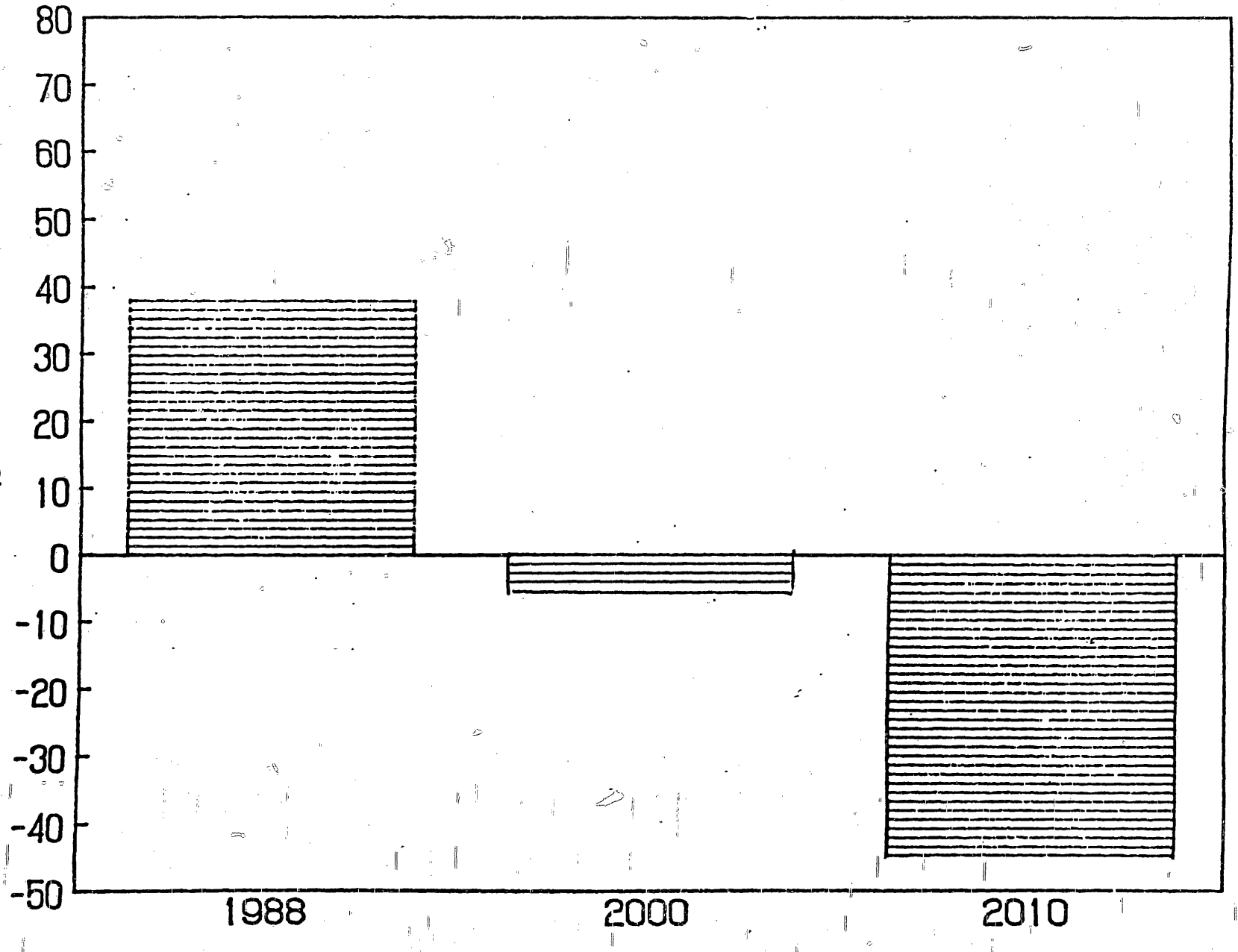
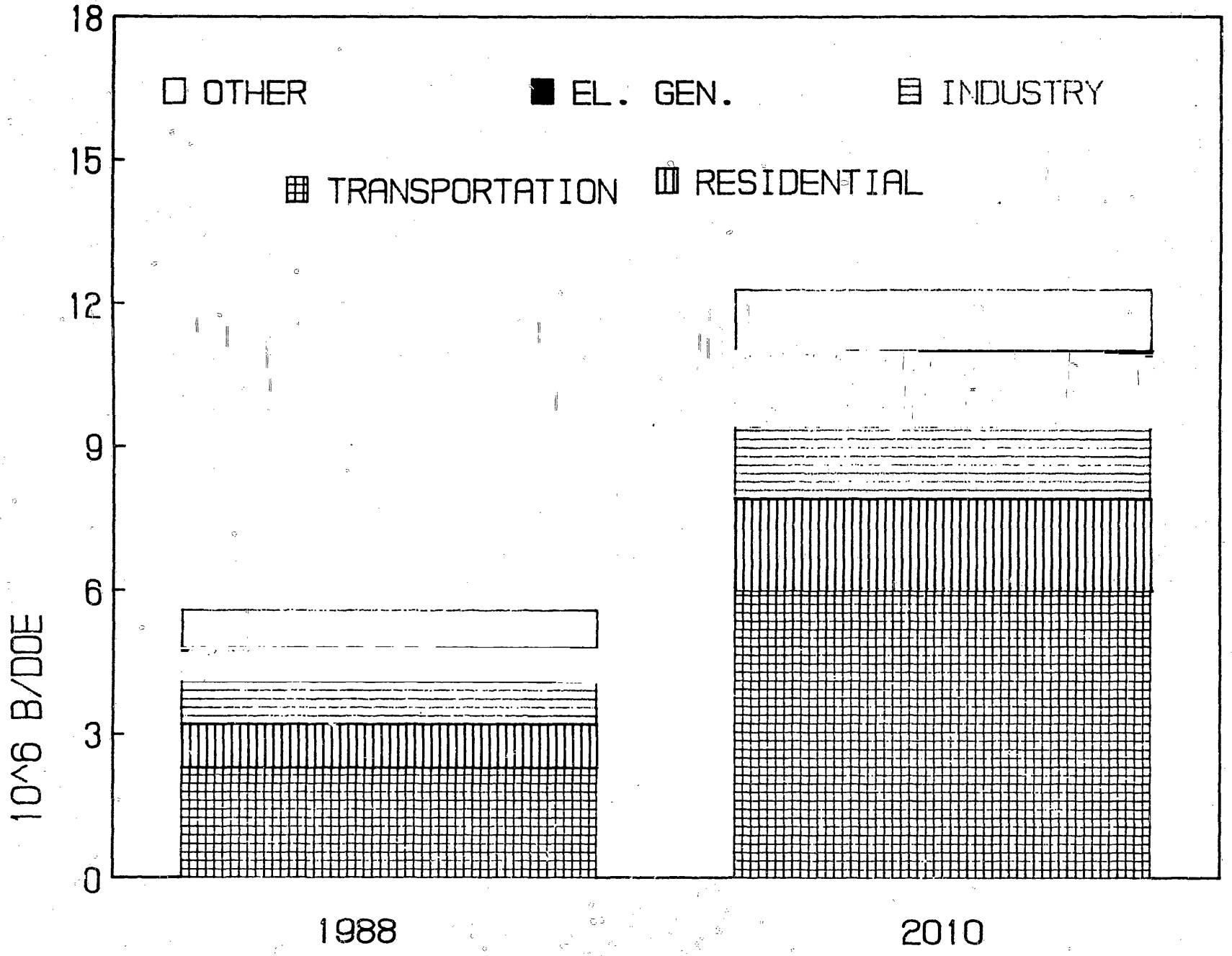


Table 11: Oil Demand/Supply Balance Forecasts

	1988			2000			2010		
	Demand	Supply	Difference a/	Demand	Supply	Deference a/	Demand	Supply	Difference a/
Difference a/									
	mmb/d								
Oil-Importing Developing Countries									
Brazil	1.116	0.58	0.536	1.786-2.058	1.0-1.01	0.786-1.048	2.182-3.45	0.65-0.66	1.532-2.79
India	1.017	0.70	0.317	1.836-1.962	0.7-0.8	1.136-1.162	3.18-3.37	0.3-0.4	2.88-2.97
Pakistan	0.188	0.06	0.128	0.381-0.421	0.03-0.03	0.351-0.391	0.669-0.727	0.02-0.02	0.649-0.707
Philippines	0.151	0.02	0.131	0.272-0.292	0.02-0.02	0.252-0.272	0.423-0.448	0.01-0.02	0.413-0.428
Thailand	0.24	0.04	0.20	0.373-0.376	0.05-0.06	0.323-0.326	0.504-0.552	0.03-0.03	0.474-0.522
Total	2.712	1.7	1.012	4.648-5.109	1.8-1.92	2.728-3.309	6.958-8.547	1.01-1.13	5.828-7.537
Oil-Exporting Developing Countries									
China	2.20	2.82	-0.62	3.571-4.594	3.0-3.32	0.251-1.594	4.10-8.34	2.40-3.60	0.5-5.94
Indonesia	0.494	1.36	-0.866	0.74-0.75	1.20-1.30	-0.56- -0.45	0.834-0.907	0.6-0.9	-0.066-+.307
Malaysia	0.195	0.55	-0.355	0.265-0.290	0.40-0.43	-0.165- -0.11	0.332-0.392	0.12-0.13	0.202-0.272
Total	2.889	4.73	-1.841	4.576-5.634	4.6-5.05	-0.474- +1.034	5.266-9.639	3.12-4.63	0.636-6.519
Excluding China	0.689	1.91	-1.221	1.005-1.04	1.6-1.73	-0.725-0.56	1.166-1.299	0.72-1.03	0.136-0.579

a/ The difference between total domestic consumption and domestic output. The range has been calculated by subtracting the lower and higher estimates for consumption from the higher and lower estimates for domestic output, respectively.

FIG 16A THE OIL MARKET IN THE 'EIGHT'



IG 16B THE OIL MARKET IN THE 'SEVEN'

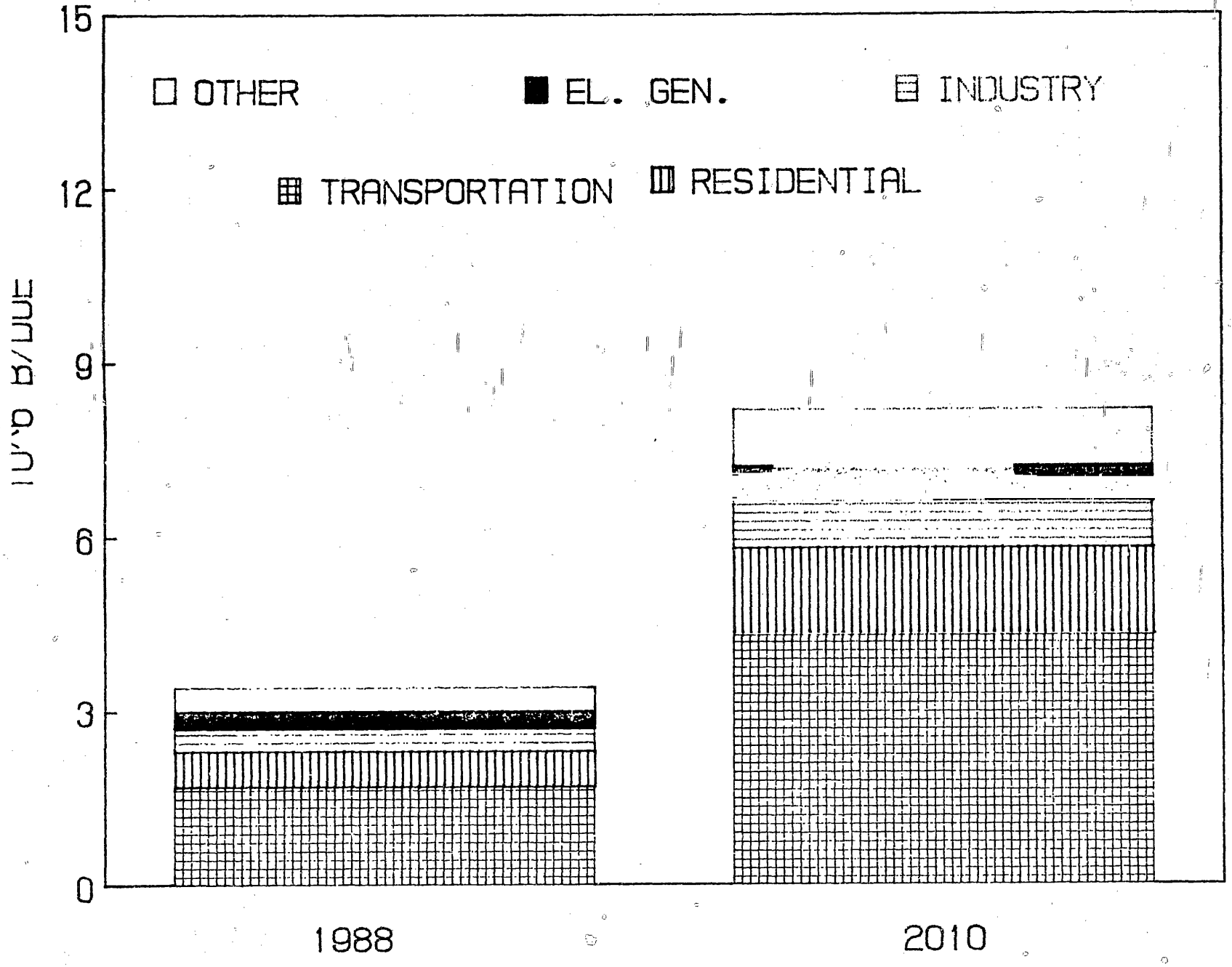
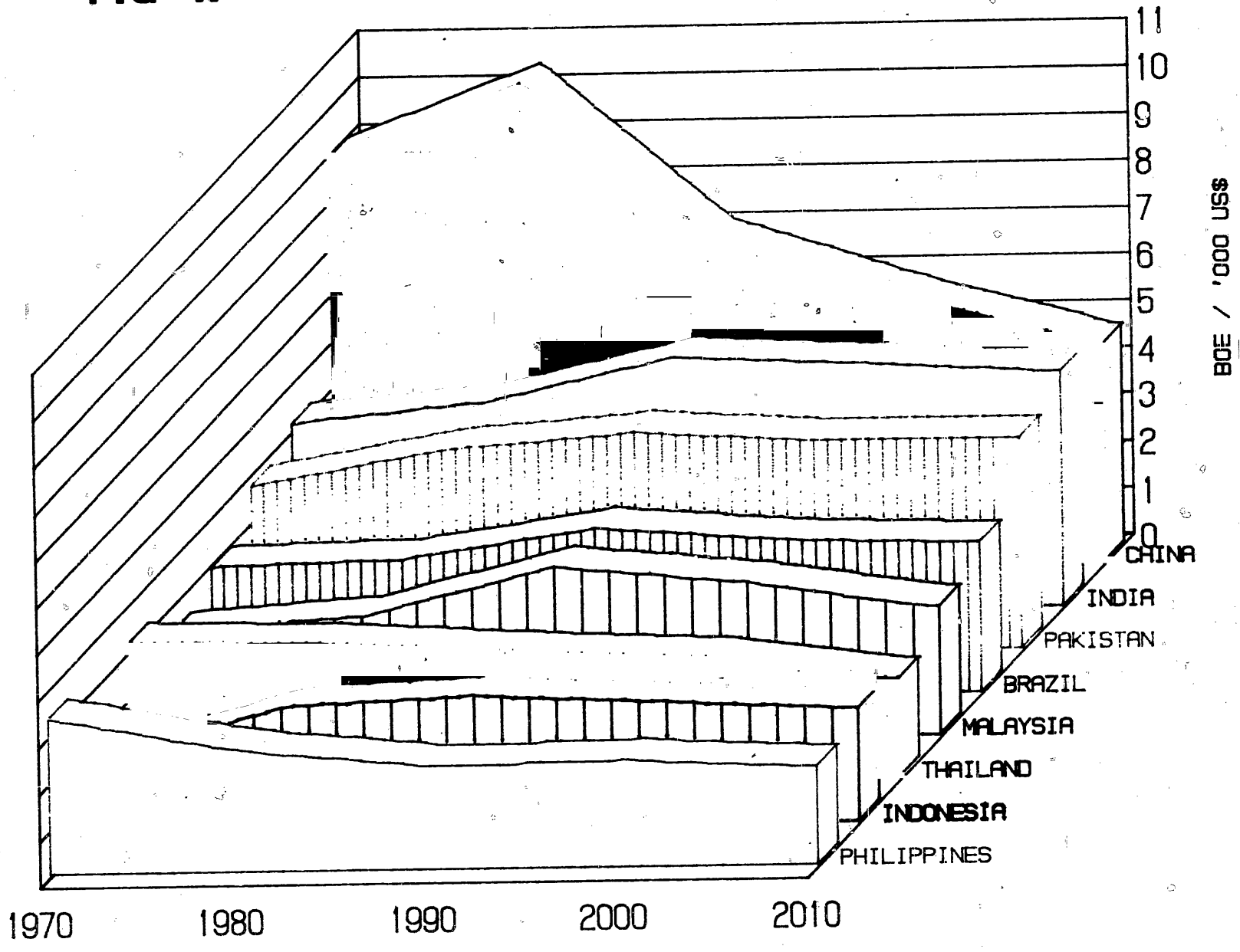


FIG 17 INTENSITY OF ENERGY USE



The difference between the two projections represents by 2010 a potential saving of some 15 mb/doe of energy in the eight countries. The impact on oil of improved efficiency and substitution on oil consumption is of the order of 6 mb/doe by 2010 (Table 12A) with the potential for efficiency improvements being largest in China where the intensity of energy use is the highest compared with other countries in the study group. Clearly, change may occur faster than we have assumed, particularly in the first decade of the next century, as a result of global or local environmental initiatives or, as yet unknown, technological innovations. It is also feasible that technology transfer, improved practices, and substitution will occur at a weaker pace than assumed. Nonetheless, it is clear that growth in developing countries' use of energy, and oil in particular, does not have to be at the same high rates as in the past in order to maintain an acceptable level of economic growth.

The potential for energy savings is the largest in the residential and commercial sectors (42%) followed by the transport sector (23%) and the industrial sector (21%) (Table 12B). In the residential sector the possibility for energy savings is largest in coal use, mainly due to the heavy weight of China's residential sector where coal use accounts for about 87% of total commercial energy consumption. Excluding China, the energy savings potential seems largest in the industrial sector representing of the order of 26% of total energy use of the seven countries by 2010. Due to the continued spread of urbanization and the switching out of traditional fuels, the potential for commercial energy savings (derived from the difference between the model-based high case and the base-case analytical forecasts) for the seven country group (excluding China) is limited by the use of energy efficient household appliances. The small difference between the residential sector energy consumption forecasts derived from the two methods is due to the fact that both scenarios envisage continued expansion of electricity use.

Table 12A: Comparison of Demand Forecasts for Year 2010 (MBDOE) (%) a/

	"Eight" Countries		"Seven" Countries	
	Primary Energy	Oil	Primary Energy	Oil
Model	66.7	18.2	26.21	9.79
Analytical	51.3	12.3	21.27	8.18
Difference	15.4	5.9	4.94	1.61
Potential Savings	23.0	32.4	19.00	16.40

Table 12B: End-Use Potential for Energy Savings (%) a/

	"Eight" Countries	"Seven" Countries
Transport	23	11
Industry	22	26
Residential Services	43	8
Total (Direct Markets)	27	17

a/ Difference between the model-based projections (high) and analytical projections (base-case), as percentage of the high case.

APPENDIX I FUTURE ENERGY DEMAND IN THE SAMPLE DEVELOPING COUNTRIES

"THE EIGHT"

	1988	1990	2000	2010
	('000 mb/doe)			
Primary Energy				
Oil	5,601	6,011	9,249	12,264
Coal	11,624	12,466	20,022	22,959
Gas	1,035	1,155	2,666	7,120
Nuclear	40	40	212	720
Hydro, etc.	2,697	2,816	4,122	8,208
Total	20,997	22,488	36,271	51,271
Energy Demand by Markets				
Transport	2,682	2,865	4,409	6,644
Industry	6,721	7,217	12,540	17,837
Residential + Services	4,219	4,229	6,686	7,347
Total direct	13,612	14,311	23,635	31,828
Electricity generation	6,059	6,747	12,392	20,908
Oil Demand by Markets				
Transport	2,288	2,431	3,873	5,965
Industry	939	1,029	1,574	1,474
Residential + Services	893	960	1,495	1,937
Electricity Generation	648	736	1,316	1,640
Others	837	855	991	1,248
Total	5,601	6,011	9,249	12,264

"THE SEVEN"

	1988	1990	2000	2010
	('000 mb/doe)			
Primary Energy				
Oil	3,401	3,714	5,678	8,184
Coal	2,502	2,894	4,508	5,718
Gas	785	894	1,709	3,144
Nuclear	40	40	112	220
Hydro, etc.	2,127	2,216	2,672	4,008
Total	8,855	9,758	14,679	21,274
Energy Demand by Markets				
Transport	1,772	1,897	2,879	4,560
Industry	2,421	2,648	3,896	5,098
Residential + Services	1,066	1,169	2,167	3,438
Total direct	5,249	5,714	8,942	13,096
Electricity generation	3,274	3,671	5,766	8,703
Oil Demand by Markets				
Transport	1,648	1,767	2,729	4,320
Industry	419	479	624	774
Residential + Services	633	690	1,145	1,487
Electricity Generation	298	336	516	640
Others	403	442	664	963
Total	3,401	3,714	5,678	8,184

INDIA

	1988	1990	2000	2010
	('000 mb/doe)			
Primary Energy				
Oil	1,017	1,138	1,836	3,180
Coal	2,123	2,395	3,563	4,436
Gas	127	165	419	948
Nuclear	30	30	90	150
Hydro, etc.	326	326	525	1,200
Total	3,623	4,054	6,433	9,914
Energy Demand by Markets				
Transport	535	575	830	1,627
Industry	1,108	1,175	1,691	2,348
Residential + Services	388	464	1,106	1,959
Total direct	2,031	2,214	3,627	5,940
Electricity Generation	1,385	1,600	2,703	4,196
Oil Demand by Markets				
Transport	413	448	680	1,463
Industry	112	119	160	232
Residential + Services	215	259	524	773
Electricity Generation	46	50	80	100
Others	231	262	392	612
Total	1,017	1,138	1,836	3,180

BRAZIL

	1988	1990	2000	2010
	('000 mb/doe)			
Primary Energy				
Oil	1,116	1,219	1,786	2,182
Coal	233	322	445	510
Gas	70	72	310	730
Nuclear	8	8	20	50
Hydro, etc.	1,492	1,574	1,694	1,990
Total	2,919	3,195	4,255	5,462
Energy Demand by Markets				
Transport	679	735	1,070	1,409
Industry	770	860	1,271	1,515
Residential + Services	318	328	430	563
Total direct	1,767	1,923	2,771	3,487
Electricity Generation	1,190	1,290	1,684	2,221
Oil Demand by Markets				
Transport	677	732	1,070	1,359
Industry	135	155	221	250
Residential + Services	182	189	240	270
Electricity Generation	51	70	130	150
Others	71	73	125	153
Total	1,116	1,219	1,786	2,182

CHINA

	1988	1990	2000	2010
	('000 mb/doe)			
Primary Energy				
Oil	2,200	2,297	3,571	4,080
Coal	9,122	9,572	15,514	17,241
Gas	250	261	957	3,976
Nuclear	0	0	100	500
Hydro, etc.	570	600	1,450	4,200
Total	12,142	12,730	21,592	29,997
Energy Demand by Markets				
Transport	910	968	1,530	2,084
Industry	4,300	4,569	8,644	12,739
Residential + Services	3,153	3,060	4,519	3,909
Total direct	8,363	8,597	14,693	18,732
Electricity Generation	2,785	3,076	6,626	12,205
Oil Demand by Markets				
Transport	640	664	1,144	1,645
Industry	520	550	950	700
Residential + Services	260	270	350	450
Electricity Generation	350	400	800	1,000
Others	430	413	327	285
Total	2,200	2,297	3,571	4,080

MALAYSIA

	1988	1990	2000	2010
	('000 mb/doe)			
Primary Energy				
Oil	195	204	265	332
Coal	7	8	36	41
Gas	113	148	210	278
Nuclear	-	-	-	-
Hydro, etc.	28	28	38	103
Total	343	388	549	754
Energy Demand by Markets				
Transport	80	85	118	163
Industry	57	65	134	187
Residential + Services	32	35	49	67
Total direct	169	185	301	417
Electricity Generation	104	113	191	288
Oil Demand by Markets				
Transport	80	85	118	163
Industry	28	30	35	40
Residential + Services	16	15	19	26
Electricity Generation	57	60	75	80
Others	14	14	18	23
Total	195	204	265	332

THAILAND

	1988	1990	2000	2010
	('000 mb/doe)			
Primary Energy				
Oil	240	243	373	504
Coal	42	42	112	168
Gas	95	96	157	162
Nuclear	-	-	-	-
Hydro, etc.	71	71	90	135
Total	448	452	732	969
Energy Demand by Markets				
Transport	160	163	237	329
Industry	90	92	134	175
Residential + Services	61	62	106	142
Total direct	311	317	477	646
Electricity Generation	147	156	263	382
Oil Demand by Markets				
Transport	160	163	237	329
Industry	15	15	25	27
Residential + Services	37	37	62	73
Electricity Generation	17	17	30	50
Others	11	11	19	25
Total	240	243	373	504

PHILIPPINES

	1988	1990	2000	2010
	('000 mb/doe)			
Primary Energy				
Oil	151	162	292	423
Coal	25	27	80	99
Gas	-	-	-	25
Nuclear	-	-	-	-
Hydro, etc.	49	51	70	106
Total	225	240	442	653
Energy Demand by Markets				
Transport	60	68	119	188
Industry	67	67	93	120
Residential + Services	24	28	72	96
Total direct	151	163	284	404
Electricity Generation	93	106	191	296
Oil Demand by Markets				
Transport	60	68	119	188
Industry	40	40	50	65
Residential + Services	10	12	42	50
Electricity Generation	31	31	61	90
Others	10	11	20	30
Total	151	162	292	423

PAKISTAN

	1988	1990	2000	2010
	('000 mb/doe)			
Primary Energy				
Oil	188	218	421	727
Coal	36	37	82	104
Gas	183	204	299	428
Nuclear	3	2	2	20
Hydro, etc.	97	100	170	329
Total	506	561	974	1,608
Energy Demand by Markets				
Transport	87	91	219	448
Industry	155	177	274	355
Residential + Services	89	93	170	270
Total direct	321	361	663	1,073
Electricity Generation	171	190	356	563
Oil Demand by Markets				
Transport	87	91	219	448
Industry	34	48	58	80
Residential + Services	37	38	69	89
Electricity Generation	19	28	50	60
Others	11	13	25	50
Total	188	218	421	727

INDONESIA

	1988	1990	2000	2010
	('000 mb/doe)			
Primary Energy				
Oil	494	530	705	834
Coal	36	63	190	360
Gas	197	209	334	573
Nuclear	0	0	0	0
Hydro, etc.	64	66	85	145
Total	791	868	1,314	1,912
Energy Demand by Markets				
Transport	171	180	286	390
Industry	174	212	299	398
Residential + Services	154	159	234	341
Total direct	499	551	819	1,129
Electricity Generation	184	216	378	757
Oil Demand by Markets				
Transport	171	180	286	370
Industry	55	72	75	80
Residential + Services	136	140	189	206
Electricity Generation	77	80	90	110
Others	55	58	65	70
Total	494	530	705	836

APPENDIX II THE ENERGY DEMAND MODEL

Data and Variables

Commercial energy demand data were collected with the aid of a data collection matrix developed by Shell International Petroleum Company. In addition, detailed energy information was also collected from World Bank sources. Total energy consumption has been disaggregated into the following sectors:

(a) residential/commercial
(b) industry
(c) transportation
(d) electricity generation

For each of the sectors, the demand for energy is split up into oil, natural gas, coal and electricity. Oil use is further broken down into gasoline, kerosene, diesel and fuel oil.

The international crude oil price is represented by the average OPEC price. This refers to the weighted average f.o.b. price of petroleum exports from OPEC countries. In order to arrive at the crude oil prices in constant domestic currency, the price in current US dollars was converted by the exchange rate and the consumer price index. The development of the crude oil price in constant national currency is expressed with 1980 as base year. The main sources for price data include Asian Development Bank, Lawrence Berkeley Laboratory and the World Bank. The historical data for GDP, population and international oil prices are based upon World Bank sources as well as on data from Shell International. The main source of data for domestic inflation rates and exchange rates is the IMF's International Financial Statistics (IFS). A brief summary of the model, its basic structure and the explanation of variables used in the model is as follows.

Summary of the Model 1/

It is a technico-econometric model of energy demand that combines the economic determinants of energy demand (i.e., income and energy prices) with technical and engineering information, i.e., conversion efficiency (transformation efficiency) and end-use efficiency (the amount of useful energy that can be obtained from every unit of final energy).

One of the features of the model is that it distinguishes three types of energy:

1/ The original version of this model was developed by Lutz Hoffman and Lorenz Jarass under a research grant from the World Bank.

(a) primary energy (e.g., crude oil)
(b) final energy (e.g., petroleum products)
(c) useful energy (actually needed for heating, lights, ACs, etc.)

Efficiencies refer to the conversion of primary energy into final energy ("conversion efficiency") and to the use of final energy for the supply of goods and services ("end-use efficiency").

The model calculates changes in end-use efficiency. It calculates the weighted average of the actual efficiency and the technical maximum efficiency. The changes in these averages are due to sector-specific efficiency changes and in structural effect. In the case of the technical maximum efficiency, only the structural effect is present because the technical maximum for the various fuels and sectors was assumed to be constant over the observation period.

The model assumes that efficiency is price induced and is tied to the stock of capital.

By means of pass-through factor (the response of domestic prices to changes in the international price of oil), the model establishes the link between domestic prices and world prices. This also gives insights into the domestic pricing policies.

The actual real increases in the price of final energy, together with the change in the domestic real price of crude oil, were used to calculate the average pass-through factors. The domestic real crude oil price is transformed into final energy prices by the pass-through factor. (Pass-through factor = increase of real prices of final energy/increase of real price of landed crude oil, CIF, both in constant domestic currency.)

Energy demand tends to react to price changes with a lag that can stretch over several periods. Little is known about the exact structure of such lags. Additional lags are involved by the adjustment of final energy prices. In the model, such lags were incorporated in the form of a time-lag factor (smoothing factor).

The econometric parameters are broken down as follows:

a. price effect

(i) immediate response (due to the reduction in the utilization rate of energy intensive equipment).

(ii) medium/long term response (requires changes in capital stock as well as operational process).

b. output elasticities

(i) uncompensated (holds for a given stock of capital).

(ii) efficiency (which increases the end-use efficiency due to the changing equipment).

The Model

Equations used in this model - in the order they are used.

s = sector
f = fuel
t = year

(1.1) RDPOIL = (POIL + TRANS) * EXCH RATE / PRICE INDEX
(1.2) PFUELT (s,f,t) = (1+(TREL(s,f)*(RDPOIL(t)/RDPOIL(0)-1)))* PFUEL(s,f,0)
(1.3) RDPFUEL(s,f,t) = PFUEL(s,f,t-1)+(LAG*(PFUELT(s,f,t)-PFUEL (s,f,t-1)))
(1.6) ep = e(t) / (1-EFFT(t) / EFFmax)
(1.8) CP = (EFFmax/EFFT(t)-1) ^ (1/ep) * PFUEL (0)
(1.9b) dp(t) = (dr + GDP^(t)) / (1 + GDP^(t))
(1.8a) EFFT(t) = 1 / (1 + {cp/PFUEL(t)}^(1/ep))* EFFmax
(1.10) EFF(t) = (1-dp(t)) * EFF(t-1) + dp (t) * EFFT(t)
(1.14) FINED = C * (PFUEL^EPD) * (GDP^EYD) / EFF
(1.15) FINED (f,t) = C(s,f) * PFUEL^EPD(s,f,t) * CONS(t)^EYD(f) * POP/EFF(f,t)
(1.16) SUM POWERED(f,t) = [SUM FINED(el) + DISTLOSS(t) - PRIMEL(t)] / CONV(t)
(1.17) PRIMED (f,t) = SUM FINED (s.f.t) / EFFTR (f,t)

Explanation of Variables

RDPOIL	the real domestic price of oil in 1980 local currency; the CIF price seen by the country.
POIL	the world price of oil (OPEC average).
TRANS	the shipping and handling cost per unit of oil.
EXCH RATE	exchange rate between dollars and domestic currency.
PRICE INDEX	the domestic consumer price index.
PFUELT	the target price of the fuel f, in sector s, at time t.
PFUEL	the domestic real price of fuel f, in sector s, during year t.
TREL	the pass-through factor. The price transmission elasticity that is derived by the change in the domestic price of fuel f, in sector s, during a historical time period, divided by the change in the CIF crude price over the time period.
RDPFUEL	the real domestic price of a fuel.
LAG	the lag factor of price adjustment, 0 < = LAG < = 1.
ep	price adjustment exponent; equals the price elasticity of the target efficiency at very low prices.
e(t)	the elasticity of EFFT with respect of PFUEL.
EFFT	target end-use efficiency.
EFFmax	technical maximum of end-use efficiency.
CP	constant representing the fuel price at which the target efficiency is one half of the technical maximum efficiency.
dp	gross investment in period t divided by the capital stock at the end of period t; dp is the share of new equipment.
dr	the depreciation rate.

EFF	the actual end-use efficiency for time t.
FINED	the final energy demand for fuel f, in sector s.
C	a constant used to adjust the estimated final energy demand to meet the actual energy demands in the base year.
EPD	the direct price elasticity of the fuel f, in sector s.
EYD	the income elasticity of final energy demand for fuel f, in sector s.
CONS	the domestic private consumption expenditure for time t.
POP	the domestic population at time t.
SUM	sum over all x.
POWERED	fuel input of fuel f for fossil-fuel power plant.
FINED(el)	demand for electrical energy in sector s.
DISTLOSS	distribution losses of the electric grid.
CONV	average conversion efficiency of thermal power plants.
PRIMED	demand for primary fuel f (crude oil, natural gas, coal); primary electricity is taken into account in equation 1.16.
EFFTR	efficiency of conversion and transport of fuel f.

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*Includes transmission and distribution losses.

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