The OIES Review

of

Long-Term Energy Demand

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1 INTRODUCTION

> As the demand shows no sign of reduction in the rate of increase, it seems inevitable that the price must continue to rise until demand is reduced either by reduction in the number of motors used or by the introduction of other kinds of carburetting material. (Professor Vivian B. Lewes, 'Oil fuel', 1913).

A great deal of time and effort has been expended by industry, governments, academics and others on trying to foretell how the demand for energy will develop. In many cases the results, when compared with what actually occurred, have been abysmal and at times with hindsight, ludicrous. This seems to be the case at all levels of demand forecasting but nowhere more so than the projections made for global energy demand.

For many years prior to the, so called, 'first oil crisis of 1973' the tendency was for each new forecast to increase the levels predicted for future demand. Actual growth was at such a fast pace that forecasts were continually being left behind by reality. Forecasters were generally not bold enough to accept that growth could continue at such a pace and their forecasts continually undershot actual demand. They were seemingly just learning their lesson when the crisis came and demand fell. None the less most forecasters still went on for some years predicting a recovery to a high rate of growth. This time they had to bring their forecasts down every year as expectations were not realized. Again it took a while before they became bold enough to reduce their forecasts substantially.

Now the common wisdom seems to be that energy demand will increase only very slowly in the industrialized countries of the OECD at well under the rate of economic growth, somewhat faster in the developing countries and at a rate in between in eastern Europe and what used to be the Soviet Union.

Despite this poor track record, taking a view on the future level of energy demand and its quantification remains a necessity. The effort put into looking at, and quantifying, the demand for energy seems unlikely to diminish.

Forecasting of energy demand, whether on a global basis or on a particular market or area, requires the establishment of the best possible assessments of the present and future trend of events on which to base the detailed results. Forecasts ought to be derived logically from a series of reasonable assumptions chosen after a thorough study of all the information available. This is, unfortunately, one of those ideals that in practice is rarely attainable and, even when it is, scarcely offers any more guarantee of success for the results than a less thorough approach.

Clearly, a suitably cynical and flexible approach has to be adopted towards

the results of any kind of forecast, however sophisticated or detailed the methodology employed. None the less, the process of forecasting, inextricably linked with planning, often has as much, if not more, value than the actual results. This is particularly so if use is made of scenarios which tell a consistent story encompassing the various assumptions made. If well chosen, such scenarios may sometimes manage to leap over the barriers imposed by the pressures of the present which have led to such misleading signals in the past.

This review does make an attempt to quantify the way in which demand for all the major commercial forms of energy will develop over the next twenty years. The main body of the review is, however, devoted to looking at the changes that are occurring now and the kind of assumptions that one might be able to take as a basis for developing future views of energy demand.

Chapter 2 looks at how and why demand has reached its current levels and whether there is any pattern of growth that can be considered 'normal' and thus suitable for future projections.

Chapter 3 looks at the changing amounts of energy that the world requires to meet its needs. It considers, in particular, the reasons why energy intensities and per capita levels of energy use differ between countries and over time and the factors influencing their future development. It poses the question of how much energy we actually need.

The regional pattern of energy demand is covered in Chapter 4 with sections on demand in the developing countries, eastern Europe, the CIS, China and the industrialized countries of the OECD. This chapter looks at ways in which the regional pattern of energy demand and trade may be different in future.

Chapter 5 looks at competition between the various energy forms in the main markets, including electricity generation, transport, industry and residential. It attempts to pick the future winners and losers considering economic and environmental factors, consumer and national preferences.

This is followed in Chapter 6 by an assessment of future energy demand evolving from and illustrated through the quantification of representative scenarios, encompassing differing views on economic, socio-political and energy development. The results from two scenarios, which represent a fairly conventional view of the way in which demand for energy will develop, are seen against the potential for more dramatic changes. The first section of Chapter 6 sets out the basis for the quantification and describes the background. The second section sets out the results for demand by major region, by energy sources and by markets to the year 2010.

The role of energy policy in a number of major countries is discussed in Appendix 1.

The quantitative results and the conclusions drawn from them can only be a rough guide to what could happen to demand and, on past form, are unlikely to match what actually occurs in practice. However, it is hoped that the chapters leading up to them will be of use to all those having to consider the ways in which the demand for energy may develop in future and the many problems such development poses.

2 THE DEMAND FOR ENERGY. IS THERE A 'NORMAL' RATE OF GROWTH?

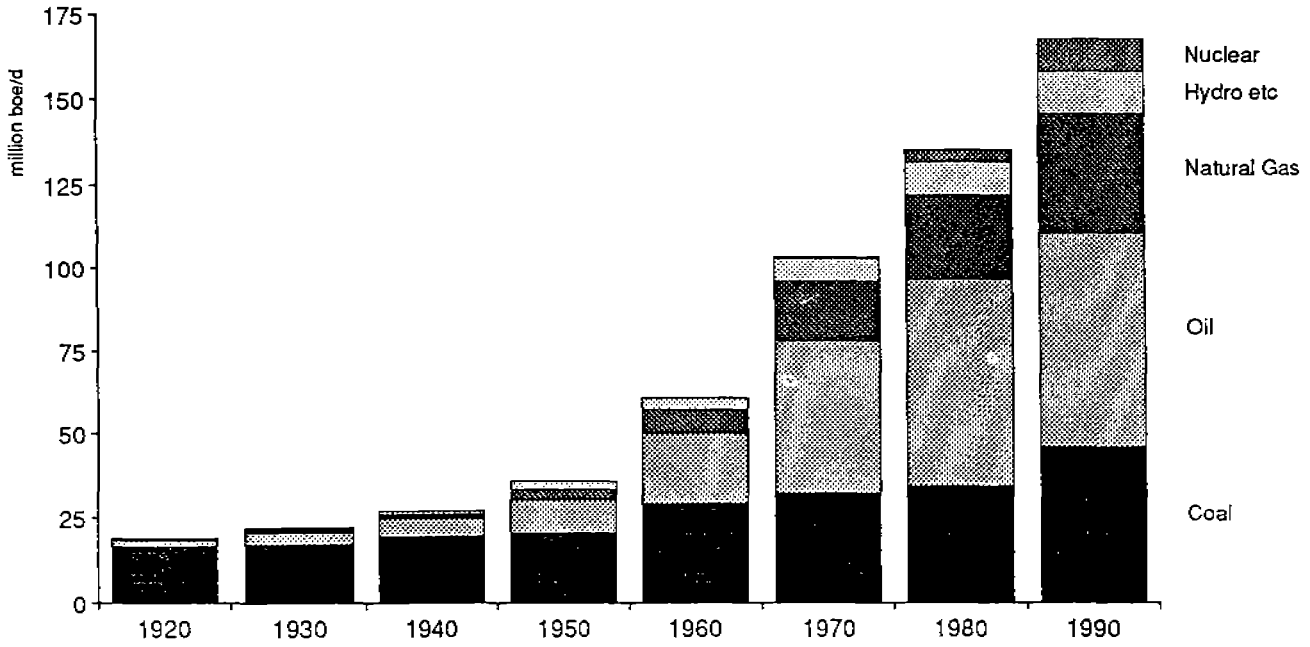
Any statistics purporting to show how much energy the world used in historical times have to be taken with the proverbial pinch of salt. After all, quite a few of the energy statistics quoted authoritatively for even recent, well-reported and energy conscious years have an element of creativity in them. None the less, one would certainly expect the last forty years or so of the nineteenth century to have been a time of rapid growth in commercial energy use. The population explosion in Europe and the Americas, the growth of rail and sea transport, the whole buoyancy and expansionism of the industrial and trade revolution, all signify an enormous expansion in commercial energy use. Indeed, as expected, the statistics do show an average annual growth rate in energy demand of 4.5 per cent between 1860 and 1900, increasing very slightly in the years running up to the First World War.

Table 1: Commercial Energy Demand. Average Annual Increases. Per cent.

1860 to 1900	4.5
1900 to 1913	4.6
1921 to 1929	4.8
1930 to 1939	1.7
1950 to 1970	5.4
1970 to 1980	2.9
1980 to 1990	2.0

Between 1860 and the beginning of the First World War, the use of commercial oil products grew from nothing to just under one million barrels per day. The demand for energy was, however, over whelmingly a demand for coal and it remained so until the end of the 1950s.

CHART 1: World Commercial Energy Demand 1920–90



After the First World War, demand for energy grew even faster and in the 1920s was increasing for the world as a whole by nearly 5 per cent every year. Then came the 1930s and, with the demand for energy actually declining in the depression years, growth over the whole decade averaged well below 2 per cent per annum.

The 1950s and 1960s saw the most rapid expansion in the use of commercial energy. In the two decades between 1950 and 1970, the amount of energy used almost trebled and annual average growth reached 5.4 per cent. At the same time, the economies of the industrialized countries were growing at around 5 per cent. It was no coincidence that this was also the era of cheap and increasingly available oil supplies and demand for oil averaged 8 per cent per annum over the same period. The 'economic miracles' in western Europe and elsewhere were in progress with help from cheap Middle East oil. There was a widely held perception that energy demand growth and economic growth were naturally and continually linked in a one-to-one relationship. The world seemed to have discovered the secret of perpetually high economic growth.

The 'normal' growth rate for global demand for energy seemed in those days to lie somewhere between 4 and 6 per cent per annum and many forecasts were made and plans implemented on that assumption. Few, if any, observers predicted the oil price increases that contributed to two major world recessions in the next decade and made nonsense of so many detailed and apparently authoritative energy forecasts. The excess capacity in terms of oil refineries, coal mines, nuclear physicists and so on that stemmed from this over-optimistic forecasting has still not completely disappeared.

Although the amount of coal used continued to increase globally, this was also an era of massive interfuel substitution, particularly by more efficient oil products. Oil was the preferred fuel and its price low and fairly stable. Indeed, overall energy growth rates would have been even higher in the 1950s and 1960s if this substitution had not taken place. If all the effective incremental volumes demanded had been met by coal instead of oil and gas, then annual growth in demand could well have averaged 7 or 8 per cent instead of 5 per cent. The substitution process had masked the real strength of growth in consumer demand for energy.

The boom came to an end in the early 1970s and, with it, the vision of continuing high growth in future energy demand that had prevailed for so long started to disappear. The high rate of growth in demand for energy, overwhelmingly in the industrialized countries of the OECD, had been caused by many factors of which a low oil price was just one. Most of these factors are still relevant to the rate at which energy demand will grow in future, particularly outside the developed economies:

- During the 1950s and 1960s, mechanization and expansion of heavy industry in major countries continued and industrialization began in many developing countries.

- There were substantial and rapid increases in the numbers of cars, in movements of freight and in the use of air transport. For example, the number of vehicles in use in the OECD countries quadrupled between 1950 and 1970. In the previous two decades they had only doubled.

- Personal disposable incomes rose at an unprecedented rate, with associated increases in living standards. Standards of domestic comfort expanded rapidly, with central heating and cooling in particular becoming significant as an increasing source of energy demand in western Europe and the USA. Most markets were still at the bottom of the lower part of the saturation curve in the 1960s with saturation seemingly a long way off.

- In the 1950s and 1960s traditional sources of energy such as wood were still being replaced by commercial sources of energy in Europe and other developed areas. In developing countries this process of substitution was beginning to accelerate.

- The affordability of energy in relation to other inputs, labour and capital, improved dramatically. Energy prices fell in real terms over most of this period. Post-war reconstruction and economic growth worldwide were certainly strongly helped by low energy prices.

- There was a generally free and widespread availability of oil and to a lesser extent natural gas. This was linked with intensive marketing efforts by energy suppliers and marketers, whether utilities or private companies.

- The massive post-war electrification programmes of the developed countries pushed energy demand considerably. Electricity production in the UK, for example, quadrupled between 1950 and 1970. Extensive and rapid penetration of electricity had a marked effect on overall reported energy demand, particularly through the relative inefficiency of its generation compared with the direct use of fossil fuels.

- The use of coal continued to expand during this period often in old machinery using inefficient processes. This led to a higher level of demand than if all incremental energy needs had come from oil or gas.

- There was a relative absence of environmental concerns to inhibit energy use; the belching smokestack was still seen as a welcome sign of progress.

Many of the above factors were already changing in relative strength and influence in the industrialized countries well before the events of 1973. The broader economic and political situation changed dramatically in the 1970s and, with it, perceptions of future demand growth and of prices. The effects of the two oil price shocks of 1973 and particularly 1979 were to help reduce annual growth in world demand for energy to an average of just over 1.5 per cent per annum through the 1970s and the first half of the 1980s. Weaker prices in the 1980s and particularly the oil price collapse of 1986 encouraged growth in demand but it still averaged only some 2 per cent per annum throughout the 1980s. This was roughly in line with the increase in population but contrasted with growth in world GDP which was around 3 per cent. What had been 'normal' rates of growth in demand for energy, matching and sometimes exceeding economic growth, disappeared. Growth in energy demand became substantially lower than that for GDP in most western industrialized countries; the linkage between energy and economic growth seemed to be weakening. Oil demand was affected most of all, with an absolute fall in volume in North America and western Europe in the early 1980s, and near stagnation thereafter.

Beneath the broad global indications are, of course, a web of many factors other than the direct price effect that has helped to keep growth in energy demand at a modest pace in recent years. As in earlier periods, there were also very significant regional and national variations. Until recently the slow growth of the 1970s and 1980s was largely confined to the OECD countries; demand

continued to grow rapidly in many developing countries and in the old 'East bloc'.

For most of the time since commercial energy was first used on a substantial scale, demand has grown at a rapid rate, usually between 4 per cent and 5 per cent per annum. Apart from the depression years of the 1930s, it is only in the last two decades of the 1970s and 1980s that sustained annual average rates of 2 per cent or less have become 'normal'. In 1990 overall primary demand for energy was estimated to have increased by only 0.4 per cent, the lowest since 1982.

In addition to the direct influence of price and its indirect effects in slowing down economic growth, many reasons can be given for the decline in the growth of energy demand. Clearly many of the factors that had led to the boom in energy demand were becoming less relevant in the OECD countries. Population growth had slowed and its age structure was altering in these heavy energy consuming countries. There was also the effect of economic recession unrelated to oil prices. Partly because of these factors and as a result of the rapid expansion of earlier decades, saturation effects began to be felt in many markets. As industrialization was reaching an advanced stage, structural changes took place and the share of the less energy intensive service sector increased at the expense of more energy intensive basic industries.

The discouragement of wasteful energy consumption and encouragement of new standards for efficiency of use on environmental and resource conservation grounds also became guiding principles of policy. This was aided in the 1970s, to some extent, by perceived politico-economic and physical constraints on availability. To what extent government policy actually had any effect in reducing the intensity of energy use is uncertain although some initiatives have helped. The new technology in industry, in transport and in the home that has led to greater efficiency in energy use would probably have evolved anyway without a direct connection to high prices and government policy. Certainly, the continued substitution of more efficient fuels, such as natural gas for coal, helped considerably as did steady improvements in the technical efficiency with which energy was produced and distributed.

Global demand for oil has, for most of its history, generally grown faster than total energy demand and was substituting for other fuels at a rapid rate in all markets up until the late 1970s. At this time, with the so called 'second oil shock,' the demand for oil started to fall in absolute terms on a global basis. In most of the years since 1984, global demand for oil has been increasing again but at a rate and volume generally well below that for total energy.

Global demand for oil in 1990 seems to have been some 0.2 per cent below that of 1989. This was apparently the result of a combination of weaker economic growth and mild weather in Europe with the economic and political changes in eastern Europe and the USSR. Oil demand in the developing countries continued to grow although at a slower pace than in earlier years.

Table 2: World incremental demand for energy and oil.
Million Barrels of Oil Equivalent per Day.

	Incremental energy demand	Incremental oil demand
1981/1980	-1.0	-1.7
1982/1981	-0.7	-1.9
1983/1982	+1.6	-0.3
1984/1983	+5.9	+0.9
1985/1984	+3.5	+0.1
1986/1985	+3.6	+1.7
1987/1986	+4.6	+1.0
1988/1987	+4.9	+1.8
1989/1988	+3.1	+1.2
1990/1989	+0.6	-0.1

Some would say that the slowing down and, at times, near stagnation of the demand for oil in recent years is merely proof that each energy source has its day and that the use of oil is close to its peak. Just as coal replaced wood and oil displaced coal so now, perhaps, oil is being displaced by natural gas or electricity. At least that is the theory frequently put forward by those who consider that oil resources are rapidly running out or consider that fossil fuels, for various economic and political reasons, should have their use restricted. This view was popular in the 1970s, usually with widespread use of renewables being shown as the ultimate and, by implication, most worthy energy form. It tends, however, to place too much reliance on the continuation of past patterns of growth in energy demand in conjunction with fixed perceptions of supply potential.

The huge increase in energy consumption of all kinds, but particularly of oil, which has taken place over the last hundred years has undoubtedly been instrumental in raising living standards to unprecedented levels in all but the very poorest parts of the world. None the less, substantial disparities remain and it is very doubtful if saturation in goods and services has been reached, even in the most prosperous countries of the OECD. World population continues to increase substantially, at around 1.7 per cent per annum overall but at 2.2 per cent in the developing countries. Aspirations to higher living standards in the latter countries, eastern Europe and elsewhere are encouraged by the spread of western orientated entertainment media and by the increasing openness of many societies. The desire for a similar lifestyle to that in, say the USA, with all that means for energy demand is highly unlikely to diminish. Thus, many of the factors described

earlier as having led energy demand to grow at between 4 and 5 per cent per annum in the past are still valid.

In this light, the interesting question is whether the relatively slow overall growth in global energy demand that we have seen during the last two decades will remain the pattern for the next two decades. Equally of interest is whether the future growth in the world economy will rest as strongly on oil as it has done in the past.

Clearly there has been, and still is, a close link between the demand for energy and economic wellbeing. To what extent growth in energy demand is now progressively being decoupled from economic growth is not clear. There have been structural changes, substitution and reductions in energy intensity at all levels of the energy system. However, it could be that the last few years have been an exceptional period in the context of the higher rates of growth in energy demand that have seemed normal over previous decades. Certainly, a buoyant world economy moving towards success in meeting the aspirations of the populations of the CIS, eastern Europe and the developing countries would seem to require substantial increments of energy. Whether these increments will follow the same type of relationships to economic and population growth as in the past or assume the same pattern of interfuel demand is highly uncertain.

It would take a brave person to say that a particular rate of growth in the demand for energy should be considered as 'normal' on the basis of past evidence. In practice, it makes little sense to postulate on whether or not we have been in a period of abnormally low growth in energy demand over the last two decades. The relationship between economic growth and energy demand is highly dynamic and complex. A dedicated researcher might, perhaps, come up with a clear pattern of relationships between historic cycles of growth but any application of such findings to the future growth of energy demand would be fraught with difficulty. This would be not least on the question of timing of movements in the cycle. The past is also not necessarily a pattern for future changes in the measures of economic wellbeing and in the structure of energy demand.

The chapters that follow look at some of the many influences on these relationships and the way in which demand for energy in its various forms could develop over the next two decades.

3 ENERGY INTENSITY. HOW MUCH ENERGY DO WE ACTUALLY NEED?

Whether using a top-down approach with econometric energy models or a bottom-up approach with detailed market disaggregation, forecasting energy demand has to involve assumptions about the intensity with which energy is used. Such assumptions are just as necessary to a highly sophisticated forecasting process using elaborate computer programmes as to a simple 'back of the envelope' exercise.

Intensity of energy use can be related to sectoral indicators such as the energy used per household or per car, or to more global indicators such as GDP or population. Variations and changes over time in energy intensity may, however, be very difficult to interpret and understand, often being a deceptively simple expression of a complex interplay of many factors. The blind use of such historical relationships in forecasting energy demand has been one of the prime causes of misleading energy projections.

However, treated with caution, the variations over time and place in simple global intensities such as the amount of energy used per head of population and per unit of economic activity can help to encapsulate and illuminate many of the factors influencing the level of energy demand.

3.1 Energy per Capita

For many decades, per capita energy consumption has been increasing in all the major regions of the world.

Table 3: Per Capita Energy Consumption. Barrels of Oil Equivalent.

	1950	1970	1990
OECD	16.6	33.5	36.2
Developing countries	1.1	2.3	3.9
USSR	8.1	31.6	34.7
E.Europe	5.7	20.4	35.8
China	0.4	2.5	4.5
World	5.2	10.2	11.4

There are, unsurprisingly, substantial differences between the industrialized countries of the OECD and the rest of the world.

As the table shows, per capita consumption of energy in the industrialized countries of the OECD as a whole is, at 36 boe, currently some nine times that of the developing countries. This is on the usual basis of comparing conventional commercial fuel use. The amount of other non-commercial and traditional fuels which are used in the developing countries is highly uncertain, but their inclusion is still unlikely to increase current overall per capita consumption to more than 6 boe in those countries.

Clearly, the higher standard of living in the industrialized countries and the much greater extent of their industrialization, urbanization and motorization are reflected in their higher per capita consumption. Climatic conditions also play a part in accentuating the differences. Domestic heating, for example, absorbs over 10 per cent of commercial energy demand in the UK compared with less than 1 per cent in Brazil.

In the USSR and eastern Europe, per capita consumption apparently increased throughout the 1960s and 1970s more rapidly than in any other major regions. To some extent this high level of use is a reflection of climatic conditions, the sheer size of the USSR and the high level of consumption for military purposes. It is also the result of the grossly inefficient use of energy that has been encouraged by highly subsidized prices and a lack of metering. Excessive waste in all phases of energy production and distribution is endemic. There is also a certain element of false reporting and non-comparability of statistics involved. At present per capita consumption remains much higher than in many OECD countries.

Considerable diversity in levels of per capita consumption is shown even between countries of similar income levels. Substantial differences within similar groups of countries often arise from differing pricing policies and historical supply patterns. Canada, for example, apparently needs to use some 70 boe of energy per person at present compared with 58 in the USA whilst Norway, with an income per head of $18,000 appears to need 35 per cent more energy per head than Sweden with a similar income. This is partly a reflection of the substantial role played by hydroelectricity, which supplies over 70 per cent of primary energy demand in Norway, and the way in which it is treated statistically.

In many industrialized countries, including those of eastern Europe, populations are growing only very slowly, if at all. In a number of developing countries, fertility rates have also dropped dramatically in recent years. None the less, the population of the developing world as a whole continues to grow rapidly and 90 per cent of the growth in the world's population over the next decade is expected to occur in developing countries.

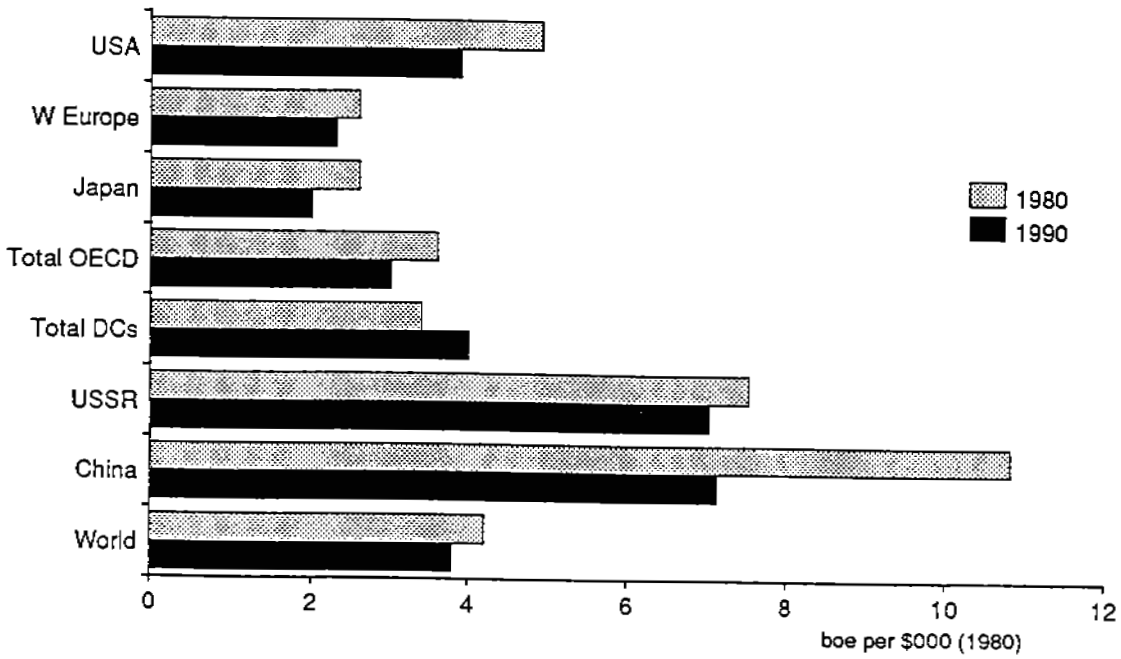
Assuming a growth in population in these countries in line with World

Bank projections but with no increase in per capita consumption, demand for energy in the developing world including China would increase by 17 million boe/d over the next twenty years. Thus, the expanding population of the developing countries, without any increase in energy needed per head or in absolute demand in the developed countries, could result in a future increase in world demand for energy of around 0.5 per cent per annum. In practice, short of a global catastrophe, it is unlikely that per capita consumption in the developing countries will actually remain at current levels.

3.2 Intensity of Energy Use in Relation to Income

There are also considerable differences amongst countries in the intensity of energy use in relation to economic and physical output. An overall intensity of energy use is often represented in broad terms by the amount of commercial energy consumed in relation to GDP.

CHART 2: Intensity of Energy Use, 1980 and 1990



A striking feature of the change in energy intensity over the last ten years is the decline in the OECD as a whole compared with increased intensity in developing countries.

Variations in energy intensity in relation to national income are considerable at all levels of development and are as wide amongst industrial and post-industrial countries as amongst those still in the early stages of development. Despite the strong connection between the use of energy and economic growth, the variation between countries even at the same level of development can be remarkable. Australia, for example, with roughly the same income per head as France uses 40 per cent more energy to support each $1,000 of income.

Within the aggregate measure of energy intensity, many factors are at work whose actual impact is difficult if not impossible to isolate. Some are common and some are specific to the conditions that exist in individual countries.

A number of the factors involved continue to encourage growth in intensity, particularly in developing countries.

Industrial growth. Rapid urbanization and industrialization accompany one another during economic development. In South East Asia, industrial expansion is averaging around 10 per cent per annum and in South Asia 7 per cent, although in South America it is close to being static at present. It is, however, the pattern of industrial activity that is a major determinant of energy intensity.

The basic industries needed to support the initial stages of economic expansion are substantial energy users. The production of fertilizers, iron and steel, plastics and paper require considerably larger inputs of energy per output value than do the manufacture of electronics or motor cars. Thus, even if the specific intensities of individual industry sectors stay the same, faster growth and a bigger role for heavy industries will increase overall energy intensity. This effect may, to some extent, be offset in developing countries by the greater potential efficiency of the new equipment although not all the potential for this kind of technological leapfrogging may be realized. In many developing countries the utilization of manufacturing facilities fluctuates considerably due to the impact of, for example, transport bottlenecks, payment difficulties and bureaucratic interference. At the resulting low levels of use, efficiency usually suffers resulting in an increase in energy intensity.

Urbanization. Urban populations are expanding at some 5 to 6 per cent per annum in developing countries. This permits more economies of scale but requires much more transport of goods and people. Food must be transported to urban centres. Production activities which were carried out using human or animal energy in rural areas shift to sources outside the household which require modern commercial energy and products are marketed over a much wider area. The main effect of the spread of urbanization and the expansion of the service sector on energy intensity is, thus, usually through rapid growth in motorized transport. There is still substantial scope for greater urbanization and, with it, motorization in most developing countries; at present only 37 per cent of their population is urbanized compared with 77 per cent in the OECD as a whole.

Motorization. The process of motorization is much faster and more extensive than in the past. Today in most developing countries there is a higher level of car ownership than occurred in the OECD countries at the same level of income. For example, the current level of car ownership in Malaysia is around 90 per thousand people. This compares with an ownership in Greece of 40 per thousand in 1973 even though Malaysia's current income per head is less than Greece's at that time. This is largely the result of a rapid decline in car prices in real terms in the post-war period combined with the development of an international car market.

In some developing countries, specific levels of fuel use by vehicles can be much higher than elsewhere. This is often due to a combination of inefficient vehicles, excessive loads, inadequate maintenance and the long distances covered by poor logistical organization. Locally built goods vehicles in China, for example, consume more than twice the amount of fuel per tonne kilometre than the vehicles used in the OECD.

Indigenous energy. The existence of a substantial indigenous energy industry, whether, for example, involving oil or coal production or fast-growing electricity generation also tends to increase a country's energy intensity. There are always energy losses in the production of energy, ranging from a few percent of the input in the case of oil or gas to over two-thirds in the case of electricity generation. In some countries the possession of very substantial resources of energy makes for its extravagant and wasteful use, as with oil and gas in some Middle Eastern countries.

Traditional fuels replacement. The use of traditional fuels is declining or at best stagnating, generally through a combination of rapidly reducing resources and increasing urbanization. In some countries with a relatively abundant supply of biomass, such as Indonesia and Brazil, a surprisingly high level of these fuels is used in industry. More generally, however, traditional fuels are consumed largely for basic cooking, lighting and heating in the home. Intensities of commercial energy demand are pushed upwards as kerosine, LPG and electricity, substitute for traditional fuels in these applications. This effect is, however, tempered by the newly adopted fuels being much more efficient in use.

It is difficult to assess with any real hope of accuracy the amount of traditional fuels still in use and the rate at which they will be replaced. According to the UN Food and Agricultural Organization and World Bank data, about 3 billion people currently rely wholly or mainly on traditional biomass fuels in their homes. Average consumption levels are in the range of 1.5 to 2.5 boe per capita, mostly for cooking. Efficiency is very low, perhaps 15 per cent at best, compared with the efficiency of a commercial fuel such as LPG at, say, 60 per cent.

A complete substitution of these biomass fuels would involve a once and for all additional demand for commercial fuels of the order of 4 million boe/d. This is only 2.5 per cent of current total demand for commercial energy and only 7 per cent of oil demand if it were all to be substituted by oil products. Some use of

traditional fuels in, for example, South East Asia is self sustaining and likely to continue. Thus although further substitution of traditional fuels will affect commercial energy intensities, the overall effect will not be dramatic.

Patterns of consumption. Urban households and buildings in developing countries have the same kind of equipment supporting the same energy needs as those in the OECD although levels of comfort, efficiency and fuel mix vary considerably. Many families, even at low income levels, have refrigerators and television sets. Higher income families also have water heaters and air conditioners. Also, the size of individual households is getting smaller. This tends to increase overall intensity as, all things being equal, fuel use is more related to the size and number of rooms in the dwelling.

In addition, modern manufacturing technologies and materials have significantly lowered the effective cost of many consumer goods. Thus, equipment is now generally cheaper to own and should be more efficient to run than when it was first introduced to OECD countries. Global distribution systems have also increased the accessibility and universal nature of many consumer goods. People in developing countries can thus purchase many such goods at a far earlier point in the development cycle than people could in today's developed countries. Equipment does, however, tend to be less energy efficient in application than in the OECD countries.

Fuel subsidies. A number of developing countries still heavily subsidize certain fuels, particularly those used for household consumption. There are also differential pricing policies that encourage excessive use of energy, particularly by state-run industries such as fertilizer factories, prestige steel works or power stations. The continuation of such special energy pricing or the guarantee of outlets for the goods they produce has been clearly shown to reduce efficiency by isolating them from the need to improve the way in which they use energy.

Electrification. The tendency towards increasing overall energy intensity with development is also encouraged by the growth of electricity generation. Electricity is favoured as a key element of urbanization and industrialization and of development generally. The losses inherent in electricity generation have an upward effect on overall recorded primary energy intensity as electricity increases its share of markets. There are also associated, substantial 'losses' in distribution and transmission that are often well above the levels normal for the industrialized countries of the OECD.

Despite the foregoing catalogue of factors encouraging growth in intensity, their effect is likely to be tempered in future. Other factors may mean that demand will not be set so inexorably on a fast upward trend as in the past.

Natural gas. Many developing countries with indigenous natural gas have been slow to develop its use for internal markets. This is now changing with substantial investment in production and distribution facilities. The wider use of what is

usually a highly efficient fuel must have an impact on energy intensity.

Pricing policies. Partly allied to greater use of gas is a more realistic approach to pricing policy. In general, a more confident approach by many governments to the removal of subsidies on domestic fuel use and on supplies to state industries, is stimulating the more careful and efficient use of energy. Fuel substitution by more efficient fuels such as gas is being encouraged by changes in relative pricing policies. Electricity prices may also benefit from the move in some countries to allow private investment in power utilities. A greater use of electricity would, however, only improve the intensity of energy used in the final demand in the market place.

Technological improvement. This is also bringing with it greater energy efficiency; it may be an automonous process or be induced by rising energy prices or shortages. If developing countries adopt the most efficent technologies now available and operate them adequately they should achieve average energy efficiencies that are higher than those in industrial countries with older and less efficient infrastructure and equipment.

Certainly in future we should continue to see a continuation of the trend towards obtaining more use from less energy. Appliances, machinery, vehicles and so on are getting more efficient all the time. Commercial energy demand in households and in the service sector appears to be growing only slowly in many advanced developing countries such as Malaysia and South Korea. More efficient equipment and improved utilization seem to be already countering the upward effects of income. Generally, the continued expansion of the service sector and increased purchase of appliances helps to accelerate the move from kerosine to more efficient LPG and electricity. New technology will continue to provide a constant stream of new consumer products but these should tend to be less energy intensive than the products they replace. For example, the most efficient domestic refrigerators on the market are said to use 40 to 50 per cent less energy than the current average of models in the OECD countries. Advanced technology could reduce energy needed to 20 per cent of current models.

This leapfrogging process may prove one of the most potent in reducing future energy intensities in the developing countries. The rate of improvement in overall energy intensity will, however, depend heavily on the pace of economic growth, providing adequate access can be obtained to the best technology.

Industrial structure. The switch in emphasis in the economy from, say, a chemical industry in which energy costs may represent between 30 and 40 per cent of total costs to an electronics industry where energy is less than 5 per cent of their total costs, also has an additional effect. The impact of changes in oil and energy prices, whether up or down, is generally weakened and with it the leverage that can be exerted by suppliers and by government policies on taxation.

Information flow. A key element in determining the future development of energy

demand is how quickly the enormous gap between the efficiencies of the best available equipment and the equipment actually purchased and used can be narrowed. The rapid diffusion of information, changes in consumer buying habits and government policies are the main influences which clearly vary enormously from country to country and will continue to do so.

Information is available more widely and quickly than ever before and the exchange of technology more easily facilitated. Thus, particularly in the rapidly expanding economies of South East Asia or in Eastern Europe, one would expect to see fast improvements in efficiency of energy use. One does not have to accept completely the dramatic potential savings in energy use quoted by the efficiency propagandists; the full cost of changing over and the inertia represented by the existing stock of equipment and practice is often treated by them in a cavalier fashion.

Future changes in energy intensity will depend on the overall impact of many factors in combination, some of which have been mentioned above.

With increasing income and changing economic and energy policies, there is a gradual change in the intensities with which countries and regions use energy. The demand for commercial energy has, in the past, typically risen at a faster rate than economic growth as the development process gets underway and as commercial energy takes the place of traditional fuels. The subsequent structural change to, say, a more service orientated economy, when basic industrialization is largely achieved, leads to a levelling off and eventually to a decline in energy intensity.

At the moment, this plateau seems to occur at a national income of around $2,000 per head. The process is, of course, a dynamic one and it may well be that this levelling off will occur in future at much lower levels of income. Certainly this has been the case in the industrialized countries in the past; UK intensity peaked in about 1880 according to one source. The USA peaked in 1910 at a level some 15 per cent lower. Italy experienced its peak energy intensity in the 1950s, again at a lower level than its predecessors in the industrialization process.

3.3 Future Trends in Intensity

The apparently very high energy intensity of the CIS and the eastern European countries has much to do with the same factors responsible for their high per capita use, namely inefficiency and waste, partly related to the way in which the economy operates. The move to a market economy, with the resultant need to address the problem of the substantial 'losses' in supplying and using energy, should bring a bonus in the form of lower energy intensities. This will be helped by a greater use of oil and gas in place of coal. The growth of mass motorization and consumerism will, however, pull in the opposite direction.

In several western industrial countries, energy intensities were declining, even before the events of 1973 and 1974 and whilst oil prices were still falling. This was due largely to improved technologies in energy use combined with structural change and the substitution of more efficient fuels. With the international price shocks, came a sharp drop in the industrial countries' energy intensity; from 3.6 boe to 3.2 boe per $1,000 GDP in the first half of the 1980s. This was in contrast to developing countries as a whole, where intensity continued to increase.

Following the collapse in international oil prices in 1986, the declining trends in oil and energy intensities in the OECD countries were halted. Overall demand growth has subsquently moderated and OECD energy intensity between 1989 and 1990 remained fairly stable at around 3 boe per $1,000. In the developing countries as a whole it also remained stable at a level only slightly higher than that of 1985.

The movement in energy intensities has, however, been significantly different between individual developing countries and groupings. Energy intensities in most oil-exporting regions have generally remained below the average, due largely to the disproportionately high contribution made by the oil industry to GNP, whilst energy intensity in oil-importing countries has been relatively high. In the more prosperous countries of South East Asia intensities have fallen in recent years and may be levelling off in India and Pakistan, albeit from an exceptionally high level. In Central and South America as a whole, energy intensity continues to increase although, for example, for Brazil it has remained static since the 1960s.

It is interesting to compare what demand might have been in the industrialized countries in, for example 1990, if energy intensities had remained at their 1970 level.

Table 4: Savings in Primary Energy. 1990/1970.

	1970	1990	
	Actual	Notional	Actual
Energy intensity (boe per $1000/'80)	4.1	4.1	3.0
Demand (million boe/d)	64.5	115.6	85.1

As the table shows, demand for energy in 1990 might have been 30 million boe/d more than was actually demanded if the changes affecting energy intensity had not taken place.

There is still considerable scope for improving the way in which energy is used in the OECD. Structural change and technological progress alone, without major substitution or savings programmes, should reduce primary energy intensity alone by some 20 per cent over the coming twenty years. With faster gas penetration and positive action on investment, we would expect intensity to fall by at least 30 per cent.

Despite the potential savings in the OECD countries, a formidable combination of increasing population, urbanization and industrialization in much of the rest of the world points to continued expectations of significant growth in world energy demand. The effective level of energy use needed in future to sustain the economic growth needed to support the aspirations of the developing countries, as well as those of eastern Europe and the CIS, is not at all certain. Neither can anyone be sure of the economic, social and political structures that will be in place. None the less, as described above, there are factors at work that should, on balance we believe, have a dampening effect on the intensity of energy use. Peaks in intensity may occur earlier and at lower income levels than in the past.

In the developing countries as a whole, we would expect energy intensity to remain, at worst, close to the current level over the next twenty years. More likely, in our view, is a decline during the late 1990s and early part of the next century towards the levels of intensity common in the OECD today.

The quantification of the scenarios described in Chapter 6 gives an indication of how energy intensity might change. The world can certainly manage adequately on much lower intensities than at present. Under the most favourable conventional scenario, by 2010, every $1,000 of income is supported by just over 2.5 boe compared with just under 4 boe in 1990. There are many who say that we could manage with even less given a strong enough collective will.

4 THE REGIONAL PATTERN. WILL IT CHANGE SIGNIFICANTLY?

As the table below shows, over 70 per cent of the world's demand for energy is to be found in just ten countries. Three of these countries represent between them nearly 50 per cent of world demand.

Table 5: The Main Areas of Demand. Commercial Energy. 1990

	Total demand for energy (mill.boe/d)	Per capita energy (boe)	% of world population	% of world demand
Ten largest commercial energy consumers				
USA	39.9	58	5	24
USSR	27.5	35	5	17
China	13.8	5	21	8
Japan	8.8	26	2	5
Germany	6.9	32	2	4
Canada	5.2	70	0.5	3
UK	4.2	27	1	3
France	4.1	27	1	3
India	3.8	2	16	2
Italy	3.1	19	1	2
Ten largest developing country energy consumers				
China	13.8	5	21	
India	3.8	2	16	
Mexico	2.2	9	2	
Brazil	1.7	4	0.3	
S. Africa	1.6	16	0.7	
S. Korea	1.4	11	0.9	
Saudi Arabia	1.3	40	0.2	
Iran	1.2	9	0.9	
Argentina	1.0	11	0.7	
Venezuela	0.9	17	0.4	

Quite frequently in journals or at conferences one reads or hears statements such as 'the US with 5 per cent of the world's population consumes some 24 per cent of the world's energy' or something similar. Such statements are usually meant to imply that there is something shockingly immoral in such a fact of life.

The fact that the developing countries, excluding China, consumed only 19 per cent of the world's energy in 1990, although they contain over 50 per cent of the world's population, is no real basis for moral judgements. It does indicate, however, the enormous potential for additional demand for energy and for dramatic changes from the present geographical pattern of demand. It also highlights the challenges that will have to be met in making the energy available or reducing the need for it.

The regional distribution of energy demand is already very different now from twenty years ago and seems likely to change at least as significantly over the next twenty years. In 1970, the OECD countries consumed 63 per cent of the world's energy and the developing countries 8 per cent, with the USSR, eastern Europe and China making up the rest. In the past twenty years, the OECD's share has fallen to 51 per cent and the developing countries share increased to 19 per cent, with the others also having increased their overall share. The faster rates of growth in population in the developing countries than in the OECD countries or eastern Europe and particularly the early stages of economic development of so many of them seem certain to lead to continued above average rates of growth in overall demand for commercial energy. Given effective economic and trade policies, change in the relative significance of the main regional groupings may well occur at a faster rate over the next twenty years than over the past twenty.

The effect of these changes in the regional demand pattern on the future supply, trade and type of energy demanded should result in a major impact on the structure of the energy business over the same period.

4.1 Developing Countries

There are around 120 countries usually classified as 'developing'. They encompass a very wide range of circumstances and experience, from the sparsely populated and wealthy oil-exporting countries of the Middle East to the densely populated and resource poor countries of sub- Saharan Africa. Just nine countries accounted for half of the total demand for energy in the developing countries excluding China in 1990. Three, India, Mexico and Brazil, accounted for 25 per cent.

Economic performance varies considerably, from the resilience and remarkable growth of the South East Asian countries and of India to weakness in South America and Africa where many countries faced crises of debt and declining per capita incomes in the 1980s. In 1990, income per head ranged from $80 in Mozambique to $18,400 in the United Arab Emirates.

To improve living standards in the face of substantial increases in population, within changing and often difficult political and trade conditions, is the key challenge. Some, such as the newly industrialized countries of Taiwan and Korea, have successfully faced the challenge; others such as Malaysia, Thailand and Indonesia are following, whilst others have scarcely begun. For the appropriate and efficient use of energy, conditions for success are perhaps more favourable now than ever before. The types of equipment and technology for producing and using energy that are now available are less expensive and more efficient than those available in the past. The developing countries are also benefiting from improvements in energy utilization which have taken place, particularly since the events of 1973. In addition, technological cross-fertilization between developing countries is increasing and there is a greater willingness to look at more sustainable forms of growth.

In individual countries, particularly in Africa and parts of South America, distorted markets and subsidized energy prices continue to hold back the introduction of efficient technologies and the optimization of energy use. However, there is a new climate for realistic pricing policies and for the encouragement of private capital and enterprise in many countries, although action is often still hampered by entrenched bureaucratic and political interests. Countries that do not make the necessary economic and bureaucratic reforms will continue to have difficulty in funding and implementing the energy supply projects such as electricity or gas grids and fuel distribution networks that are basic to a sound economy.

As Table 6 shows, of the main developing regions only the Far East and South Asia are currently net importers of energy whilst all the others are net exporters. Almost all the net exports from the Middle East are of oil as is the bulk of exports from the other two exporting regions, although they both export some coal and gas.

Table 6: Net Trade Balances in Energy. Million Barrels of Oil Equivalent per Day.

	1990	2010
South America	+ 2.9	+1 to +3
Africa	+ 5.5	+2 to +3
Middle East	+14.2	ca25
South Asia	- 0.4	-2 to -1
Far East	- 2.2	-5 to -3
Total developing countries	+20.0	ca+20 to 25

Note: +: net exporter. -: net importer

The estimates for 2010 are based on a range of economic growth rates which spans that which has prevailed over the last ten years and also on a fairly moderate view on investment in the development of energy resources. The general pattern of trade balances for energy will change over the next twenty years, but not dramatically so providing available indigenous energy resources are harnessed adequately. South America and Africa remain net exporters but deficits increase significantly in South Asia and the Far East. The developing countries as a whole remain net exporters to the rest of the world. This overall pattern does, of course, hide the very varied situation of the individual countries within the regions.

By the turn of the century many countries such as Malaysia and Indonesia which now export oil may well have become net importers. This may be compensated to some extent by increased exports of coal and gas. There will be increased reliance on the Gulf exporting countries and rising oil imports will further burden countries already suffering from high oil import bills. Part of the difficulty may be solved by the development of additional natural gas supplies and the establishment of domestic infrastructures for gas use, but much depends on the overall trade climate and the ability to acquire foreign exchange.

An indication of the present pattern of commercial primary energy demand is given below.

Table 7: Pattern of Commercial Energy Demand. 1990. Per cent Shares

	South America	Africa	Middle East	South Asia	Far East
Oil	53	40	60	33	48
Natural Gas	18	15	36	8	9
Coal	5	33	2	46	29
Hydro etc	24	12	2	13	14
Total	100	100	100	100	100
(million boe/d)	(9.7	4.8	5.0	4.6	6.9)

The substantial use of coal in Africa and South Asia is largely a reflection of the large and well-established coal industries in South Africa and India and is not typical of the other countries in these regions. Oil is generally the dominant fuel, with hydro and natural gas playing a larger or smaller role depending on the

extent of the indigenous resource and its state of development.

Achieving an adequate supply of energy is already a serious problem in many developing countries and is often at the heart of their economic difficulties. In Pakistan, for example, stagnation in the supply of natural gas has led to severe gas shortages which have prompted the government to take measures to restrain demand growth through allocation by region and user. This in turn has led to electricity shortages, increased oil imports – which have put severe pressures on the balance of payments – and reduced industrial output. There are many other examples of supply problems hampering the provision of adequate energy, ranging from the single unreliable nuclear plant that has to supply all of the Indian State of Rajastan's electricity to the tragic consequences of the firewood shortage in the Sahel. The development of energy resources and the financial and technical abilities to bring them where they are needed are basic necessities for successful economic development.

The supply constraints will not be removed overnight. There does, however, now seem to be more realism with energy policies increasingly based on economic merit and with private investment playing a key part.

Over the last ten years, energy demand in the developing countries as a whole has grown faster than GDP although in the last couple of years it has been roughly in line. Structural change in the faster industrializing countries, which are themselves growing in number, with some fuel substitution and efficiency improvements brought about by modern technology and better procedures, should keep growth in energy demand from moving back above economic growth. Indeed by the late 1990s, energy intensity overall in the developing countries as a whole could be falling. This could occur solely through normal tendencies towards structural, technological and fuel changes without any of the more innovative actions advocated for 'sustainable growth'.

A continuation of the present level of energy intensity could mean a growth in energy demand of around 5.5 per cent annual average increase and a demand of around 95 million boe/d by the year 2010 for the developing countries alone. This is more than total demand for the OECD countries at present and is not likely to occur.

Energy intensities will fall but, even with a fall in energy intensity of 30 per cent, the primary energy needed to support an increase in per capita income of around 3 per cent per annum could still be as high as 60 million boe/d by 2010. This compares with present demand of around 31 million boe/d. Making available nearly 30 million boe/d of incremental energy is a formidable challenge on top of the additional supply projects needed to replace depleted oil and gas fields, worn out power plants and so on. The bulk of investment seems likely to continue to be in electricity generation. Indonesia, for example, expects demand for electricity to grow at 15 per cent per annum over the next five years at least. At this rate they will need to put in place by the end of the first decade of the next century

generating capacity equivalent to that in the UK at present.

These are of course very gross numbers which can be manipulated in many ways and there is no substitute for an individual country-by-country and market-by-market based forward analysis. However, it does give an indication of the range and uncertainty of potential demand and the need to improve the efficiency with which energy is used.

4.2 Eastern Europe

The early euphoria over political and economic changes in eastern Europe has now settled down to a more sober realization of the enormous problems that all these countries face in making a decent life for their citizens. Energy is at the core of any economic revival but the problems posed in meeting existing demand and the substantial volumes of suppressed demand seem almost insurmountable.

At present this region uses considerably more energy per unit of economic output than western industrialized countries and more even than most developing countries. This is mainly because of substantial and inefficient use of indigenous coal, much of which is poor quality lignite, and the inherent problems of their old command economies.

Prices charged for energy in the past have borne little or no direct relation to the cost of production and in many cases prices have been lower than production costs. As a result there has been little incentive to process or consume energy efficiently.

Ending the old system of economic management and control and replacing it by a market-based economy is a slow and piecemeal process. Understanding and planning in the energy sector are further hampered by the unreliability and poor quality of most official data. However, changes are occurring. There now seems to be a fairly general acceptance that existing energy institutions must be restructured, clarified and revitalized and that the present wasteful use of energy be adequately addressed.

In addition to the problems of obtaining enough suitable energy and ensuring its efficient use, there is the urgent need to reduce environmental pollution before the effects on population and productivity become irreversible. Much of the problem is caused by inefficient use and production of energy and particularly by the heavy reliance on coal in four out of the five independent eastern European countries. In Czechoslovakia, coal accounts for more than half and in Poland more than three-quarters of primary energy consumption.

An obvious way of tackling these problems is to improve the outdated and inefficient industrial infrastructure as well as importing better quality forms of energy. Both present considerable difficulties of payment and in attracting

investment.

Severe logistical problems, which involve substantial investment in new pipelines, power grids and other conduits for international movements of energy, also have to be overcome. There is also a lack of an adequate market and distribution infrastructure for energy. Thus, for some time to come considerable emphasis will remain on the continued use of indigenous resources. This could in many cases exacerbate environmental damage unless equipment and practice can be rapidly improved.

Many of the key energy decisions of the region relate to electricity generation and in some countries the bulk of the incremental base load was to have been met by nuclear. The future of many existing and planned nuclear power stations is now highly problematical because of the dangers posed by their poor design and inadequate safety measures. There may be little alternative to continuing the use of nuclear power over the next few years if pent-up demand for electricity is to be met. But there seems likely to be much wider use of gas over the longer term, driven partly by environmental anxieties. The demand for oil, particularly motor fuels and heating oils, will also increase rapidly once the economies improve and motorization takes off.

In the region as a whole, oil currently meets only 22 per cent of primary energy demand and gas only 15 per cent compared with coal's contribution of 55 per cent. All the countries of eastern Europe, with the exception of Romania, still rely heavily on the CIS for their oil and gas supplies. In 1990, dependence on the USSR ranged, for oil, from a negligible proportion of demand in Romania to 100 per cent in Bulgaria. For gas, Romanian dependence was some 18 per cent of demand, in Hungary it was nearly 50 per cent, in Poland 60 per cent and in Bulgaria and Czechoslovakia almost 100 per cent. Trading conditions are fluid with pricing moving to an international basis with payment in hard currency and new actors on the scene; the heavy reliance on the CIS for oil and gas supplies has, perforce, already been reduced.

How the level and quality of energy necessary to support improved standards of living is to be achieved, whilst at the same time reducing environmental degradation, is the main challenge in meeting energy demand in eastern Europe. There is clearly substantial scope for more efficient use of energy and for restructuring at all levels of activity. Given political stability and a modicum of economic success, leading to the introduction of modern industrial plant and practices, we would expect the pattern of energy demand to move towards that of western Europe. This may well occur much faster than expected, once the momentum for change gets under way and other industrialized states become more closely involved in reconstruction. Energy intensities will fall as heavy industry takes a smaller share of the market and as gas and oil displace lignite. This will occur partly for environmental and diversification reasons but largely because the changing emphasis on consumer needs will require substantial increments of transport fuels, high quality industrial energy and more appropriate

heating sources.

The process of change will, however, be slow and possibly uncertain. We do not expect improvements in energy efficiency to reach the levels of western European countries within the next twenty years unless the pace of gas penetration is faster than currently seems feasible. Although a doubling of gas use could well be achieved in that time, substantial tonnages of coal and lignite would still need to be used.

4.3 CIS

Although the amount of energy consumed fell in 1990, the CIS remains the world's second largest consumer of energy with a higher intensity of energy use than even eastern Europe. This is a direct result of the command economy approach to maximizing energy production. Energy prices were, and still are, very low and demand has only been constrained by the occasional physical shortages. As a result there is gross inefficiency at all stages in the processing, transport and use of energy. Distortions in the fuel mix have also been caused by a lack of adequate differentials between energy sources. The ratio of electricity prices to coal prices has been well under 3, which given at best a ratio of fuel input to electricity output of 3, is a sure recipe for waste and financial disaster.

Even before a switch to anything remotely approaching a market economy the pressure to use energy in a less profligate manner is intense. Although the CIS and specifically the Russian Republic, is the world's largest producer of oil and gas and the third largest producer of coal, an adequate energy supply has become a problem, particularly as it is the major source of foreign exchange. The claims to sovereignty and the de facto independence of the individual republics as well as the overall turmoil are likely to have a major impact on the energy scene and the outlook through the nineties is very uncertain. However, given an eventual degree of stability and prosperity one might expect further shifts to the use of natural gas, particularly in the power sector and substantially increased demand for transport fuels and electricity. Adequate economic growth only seems likely to occur as a result of western investment in conjunction with a radical change in the market structure. This goes hand in hand with improvements in the way energy is used and supplied and particularly with moves towards realistic pricing.

The effect of a move to market pricing on demand is uncertain but must result in more careful use of energy and give impetus to the introduction of new technology and more efficient practices. A Soviet Academy of Sciences study put the potential savings from using modern energy technology at around 6 to 7 million boe/d by the year 2005. Even without new technology, industry is in a position to make substantial savings. Apparently over 25 per cent of industrial products produced have no real market and would under any sensible sytem have been abandoned long ago. Just getting rid of these unwanted industries would

save over 2 million boe/d. In addition there is the massive diversion of resources to the defence industry which may be slimmed down.

The present high level of energy use, with its potential for savings, also tends to obscure considerable potential for additional energy demand. Motorization is still in the early stages – around 5 cars per 100 people compared with 35 to 40 in western Europe – housing is inadequate and there are severe shortages of electricity. To what extent the suppressed civilian demand for energy that exists, directly and also indirectly through a lack of consumer goods, can be met through greater efficiency and a reduction in military consumption is unclear.

The substantial potential for savings that is available through restructuring, conservation and substitution ought to mean that overall growth in primary energy will be constrained. Successful reform and a soundly growing economy will be the best promoters of more efficient energy use.

On balance, overall primary demand for energy seems likely to grow more slowly over the next few years as poor economic performance, muddle and massive uncertainty take their toll. If a practical system of economic relationships between the constituent parts of the CIS and the rest of the world is forged during the 1990s, then new methods and incentives will help to restrain demand growth. There is a great deal of slack to be taken up in energy use and we would not expect growth in primary energy demand to occur at much above 1 per cent average annual increase.

4.4 China

Consumption of energy per unit of GDP in China is well above that of other major developing countries. It is more than twice that of Pakistan, a particularly heavy user of energy. Compared with the European OECD countries and Japan, commercial intensity appears to be more than ten to fifteen times greater. There are many reasons for this apparently wasteful use of energy but one of the main ones is the dominance of coal and its poor quality and inefficient combustion. China is the world's largest consumer and producer of coal. Coal meets over 75 per cent of its commercial energy demand. A very high and damaging level of pollution results from the use of coal; an estimate made by the National Environmental Protection Bureau and others in China estimated that the annual emissions from the whole country reached 23 million tonnes of particulates and 15 million tonnes of SO_2 in the mid 1980s. It seems likely that China could be the single biggest incremental contributor to global warming even without taking into account the additional effects of their large-scale burning of firewood and residues and forest degradation. This is, however, unlikely to be of such concern to China as to the rest of the world and will have little influence on their use of coal through the 1990s at least.

The bulk of oil consumed in China is currently used for transport. An

assumption that the number of vehicles would treble by the year 2010, but without significant expansion of oil use in other markets, would see domestic oil demand doubling to around 4 million b/d. This would put China's current ability to export oil under severe strain and could move it into a net importing position by the end of the nineties. This points to the difficulty in reducing the need for coal through substitution. Natural gas potential is substantial but almost entirely undeveloped. It is unlikely to be an adequate substitute until well into the next century and the expansion of nuclear and hydropower can only have a minor impact within the larger China context. The potential for savings in coal use are enormous in relation to practice elsewhere but it must be questionable whether any significant changes can be achieved this century. In any case this does not address the question of how to meet the enormous amount of suppressed demand that exists, for oil in particular.

If China consumed oil at the same per capita rate as Japan, total demand would rise to an enormous 45 million b/d from 2.4 million b/d at present. More crude oil has been allocated by the Chinese government for domestic use in recent years and, combined with heavily subsidized prices for such widely used products as diesel oil, consumption has been rising rapidly. Although it is unlikely that demand will even approach the per capita levels common in many other eastern countries for many years, economic aspirations lead in that direction.

There is thus enormous potential scope for growth in demand for energy in China but, in truth, at this stage it is impossible to even guess what will actually happen. It is not only resource availability that is the problem but, as with so many other developing countries, the means to pay for the improvements that are vitally necessary if energy is to be used more efficiently and cleanly.

4.5 The Industrialized Countries of the OECD

The energy demand of the member countries of the OECD still dominates the world energy scene. Their overall economic maturity and population stability may well represent the model towards which the energy economies of other regions are moving.

The USA is the largest single contributor to energy demand in the OECD as a whole although, as the table shows, demand in western Europe and Japan is now, in total, very close.

Although the immediate effects of the first oil price shock were to reduce energy demand, by the mid 1970s demand had started to increase again. In the first half of the 1980s however, energy prices in real terms were high and economic growth low so that energy demand actually declined in absolute volumes for several years. After 1985, energy prices fell, economic growth increased and energy demand grew over the next five years at an average of 2.3 per cent per annum.

Table 8: Energy Demand in the OECD. Primary Energy Demand by Regions. Percent Shares.

	1950	1970	1990
USA	61	49	47
Canada	4	5	6
Western Europe	30	34	34
Japan	3	10	10
Australasia	2	2	3
Total OECD	100	100	100
(million boe/d)	(26	65	85)

The intensity of energy use was falling by an average of around 2.5 per cent per annum between 1980 and 1985, primarily in response to the higher energy prices and economic restructuring. In the second half of the 1980s, the improvement in energy use slowed; energy intensity continued to fall but at a lower rate of around 1.3 per cent per annum. Part of the reason for the earlier slow-down of improvements in energy intensity in the latter part of the 1980s was the strong growth in demand in the industry and transport markets. In the transport market demand is almost entirely for oil, and was affected by changes in fleet efficiency and purchasing behaviour. Consumers tended to purchase bigger and more powerful cars and, because of these behavioural and income related effects, the efficiency of the average new car increased very little or actually fell in some countries.

Over the last two years the rate of decline in energy intensity appears to have accelerated again, partly due to milder winters.

Oil had taken over the position of coal as the dominant fuel in all the main regions of the OECD by the early 1960s. It remains dominant but, as the table shows, in recent years its share has declined in the face of increases in the demand for natural gas, nuclear power and even coal.

Table 9: Energy Demand in the OECD. Primary Energy Demand by Fuels. Per cent Shares.

	1950	1970	1990
Oil	30	51	42
Natural Gas	11	20	20
Coal	52	21	22
Nuclear	0	1	9
Hydro etc	7	7	7
Total	100	100	100
(million boe/d)	(26	65	85)

The increase in coal use over the last two decades (albeit modest), as well as nuclear is a reflection of above average growth in demand for electricity and a deliberate policy of diversification from oil.

Between 1970 and 1990 electricity demand grew on average at some 7.7 per cent per annum, well above growth in GDP. As a result, the share of primary energy going to electricity generation increased from 12 per cent to 38 per cent over the same period. Growth in demand for electricity slowed in 1990 although there were wide variations amongst the regions, ranging from a growth of only 0.2 per cent in North America to 7.3 per cent in Japan. This was largely a reflection of economic conditions but a continuation of above average growth in electricity demand seems likely in all the regions through much of the 1990s.

The governments of the OECD countries have long sought to influence energy demand by levying taxes and charges on fuels and electricity and by the use of subsidies. They have been in the forefront of setting performance standards for new cars, machinery, houses and home appliances and in subsidizing public transport. During the 1970s and 1980s these efforts were mainly driven by concern about the high cost of energy and the vulnerability to disruptions in oil supply and were aimed at improving energy efficiency, helping to slow the rate of energy use and lessening dependence on oil. Policies are now being increasingly directed towards reducing environmental pollution and global warming. Some measures have been more effective than others but energy efficiency has certainly improved, although perhaps only partly as a result of deliberate policy measures. Electricity generation is a major focus for efficiency improvements as the largest single outlet for energy and as a major source of pollution where the substitution possibilities are significant. Indeed, the overall thermal efficiency of generating

electricity in fossil-fuelled power plants has increased by over 30 per cent since 1970. There is still scope for further improvement through the greater use of combined cycle plants and the combined production of heat and power.

Japan has the lowest energy intensity of any of the industrialized countries in the OECD. This is mainly because of the high contribution made by hydrocarbon fuels, its modern industry and the generally lower comfort levels in private dwellings. There is also a continuing joint effort between government and industry to maximize energy efficiency – particularly in electricity generation and distribution.

The draft energy charter of the European Commission based on the Lubbers proposals has a stated aim of promoting the construction of a Europe-wide market for energy as a means of 'promoting security of supply on the most satisfactory economic basis and developing energy activities with due regard for the environment'. The main impact on the future pattern of energy demand is likely to come from proposals for the opening up of the main international transmission grids for gas and electricity to allcomers and the expansion of interconnections between grids on a compatible basis. If the charter is successful in breaking the position of the main gas carriers it could be a significant step towards expanding the use of gas throughout Europe. This, and a more balanced use of electricity should result in continued improvement in energy intensities. It will also be aided by the removal of subsidies on indigenous European coal industries leading to a reduction in coal use.

The effect on demand of recent proposals by the European Commission for an energy tax rising to the equivalent of $10 per barrel of oil and related to the carbon content of fuels is uncertain. The objective is to meet the EC commitment to stabilize carbon dioxide emissions by the end of the century, as well as to promote energy efficiency and security of supply. If ever actually implemented the overall impact of a staggered increase should be fairly modest, possibly only reinforcing current trends towards a stable level of demand. Oil will be put at a disadvantage to natural gas and nuclear and hydro power and the concentration of oil demand in the transport market will be accelerated. Coal's position will be weakened further and the encouragement of greater gas use in power generation should increase efficiency, given that adequate supplies of gas from low cost sources are available.

In the USA, the National Energy Strategy published in 1990 devotes more space to increasing supply than to reducing consumption. None the less, savings in oil use are estimated at 3.4 million boe/d in the year 2010 of which 95 per cent are to be obtained from reduced consumption by road vehicles. Around half is expected to occur as a result of the displacement of oil by alternative fuels. Improved fuel efficiency is the other contributor. The overall approach is, however, rather weak with increased taxes being ruled out. Electricity generation is recognized as the largest single user of energy where there is considerable scope for saving and fuel substitution. The strategy hopes to reduce overall electricity

consumption by 12 per cent in 2010 over what it would otherwise have been. Integrated resource planning is also expected to help reduce the amounts of fuel required for power generation. It is hoped that the overall effect of the strategy will be to reduce consumption of primary energy in the year 2010 by some 8 million boe/d below what it might otherwise have been. This is, of course, a highly notional reduction, set against a tendentious forecast of the level of consumption that would occur if there were no changes in policy. It is also unlikely that the strategy will pass into legislation, although some parts of it may do so. There are already existing savings building up from structural changes and from underlying technological improvements which will probably continue regardless of any new initiatives. A long-term growth rate in demand for primary energy of under 1 per cent per annum is a distinct possibility.

The mixture of positive action and underlying structural change in the economies of the OECD and in their pattern of fuel use should help to reduce energy intensity through much of the 1990s and into the next century. The combination of a very slow-growing and ageing population and a degree of energy saturation in some of the major countries makes it unlikely that overall annual growth in energy demand will exceed 1 per cent per annum. It may be considerably less. Much of the growth that there is seems likely to be driven by the southern European countries, the absorbed eastern parts of Germany and perhaps Canada later in the decade.

We have developed and quantified scenarios of future global energy demand and these are described and detailed in Chapter 6. The overall incremental global demand for all commercial energy between now and 2010 totals 40 million boe/d under one of the two conventional scenarios and 64 million boe/d under the other. This compares with an increase in demand over the last twenty years of some 63 million boe/d. Under both scenarios, by far the largest increase in demand is in the developing countries. By 2010, at least 25 per cent of the world's energy demand could come from these countries as well as another 10 per cent from China. This compares with 19 per cent and 8 per cent respectively at present.

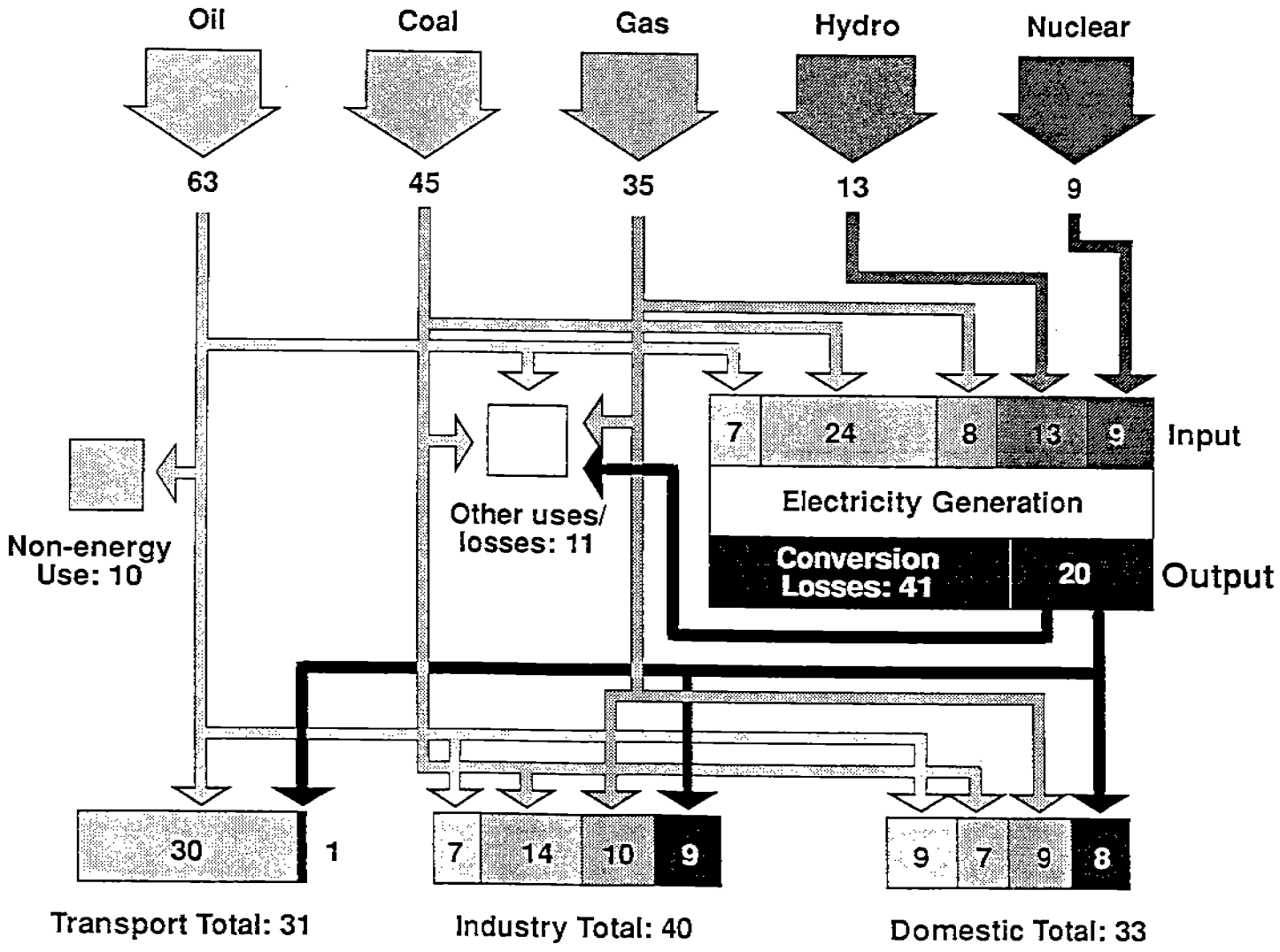
Much of this increase is in the form of oil demand which grows faster in the developing countries as a whole than in any other major grouping. With growth averaging between 2 and 3 per cent per annum, these countries will need an additional 8 to 11 million boe/d of oil by 2010. By then they will be the source of roughly 30 per cent of the world's demand for oil by 2010 compared with 23 per cent now.

The bulk of the world's incremental demand for energy over the next twenty years or so will stem from the developing countries. However, the existing countries of the OECD will, together, still represent the largest market for energy and oil.

5 INTERFUEL COMPETITION AND THE MARKETS. WINNERS AND LOSERS?

Chart 3 illustrates in a simple schematic form the flow of commercial energy for the world as a whole in 1990.

CHART 3: The Flow of Energy, the World, 1990
Million barrels of oil equivalent per day



The chart shows along the bottom the physical volumes of energy actually demanded by consumers in the main end-use markets in 1990. This market demand, of some 104 million boe/d, represents only 63 per cent of the total amount of primary energy that has to be supplied. The proportion naturally varies from country to country depending on the supply structure, fuel mix and economic

structure but usually lies somewhere between 60 and 75 per cent.

Most of the difference between primary energy required and what the end-users demand is made up of losses in electricity generation. In the example shown for the world as a whole, some 41 million boe/d is 'lost' in generating electricity although part of this is notional due to the treatment of nuclear and hydro power. The primary role played by electricity generation in any attempt to restrain energy demand cannot be overstressed. The gap between primary energy and market demand also includes, to a lesser extent, losses in moving gas and electricity, energy use in the energy industry itself and non-energy uses such as bitumen for roads.

In most countries the gap has been steadily increasing for many years as demand for electricity has grown at above average rates. This is illustrated in the table below.

Table 10: Market Demand in Relation to Primary Energy.

	Market demand as a % of primary energy demand		% of electricity in market demand	
	1970	1990	1970	1990
USA	77	72	10	16
France	80	67	8	17
Australia	70	66	11	18
Norway	71	64	24	44
Japan	73	70	14	20

As electricity continues to penetrate the end-use markets at a faster rate than other energy forms, the difference between market demand and primary energy needed is likely to continue to grow in the future. This is being countered to some extent by improvements in the efficiency with which electricity is generated.

There are also substantial savings to be made in reducing transmission and distribution losses, particularly in developing countries and the CIS. In the OECD as a whole, around 9.5 per cent of electricity sent out by power stations is 'lost'. This is unlikely to be reduced by very much in the near future. However, in India and Pakistan, for example, over 20 per cent of electricity generated disappears

before reaching the paying consumer. In the CIS, around 10 per cent and perhaps more of the natural gas produced is apparently used in its transmission or lost through leakage due to old and unsuitable equipment and general inefficiency. Despite achievements in these areas, rapid penetration in the use of electricity will almost inevitably mean that primary energy demand will continue to grow faster than actual market demand in future.

The delivered energy shown in the flow chart as market demand, is in practice converted by the process or machinery available to useful energy necessary for the service actually required. It is almost impossible to turn this demand for energy recorded by the individual markets into the needs that they actually meet, for comfort, mobility and so on in any reliable or useful way. It can be shown, however, that the real need for energy in terms of the efficiency of the processes involved is very much less than shown in the chart. After taking efficiency of application into account, a rough indication would be that only about 60 per cent of the final market demand shown is actually required in effective terms. Clearly a 100 per cent efficiency in use is highly unlikely to be achieved but there is scope for significant savings in almost all end-use applications.

Energy is just one of many inputs to meeting the world's needs and wants; something which is sometimes forgotten by those at the centre of international and national energy organizations. For the individual consumer and his government it is food, housing, heat, mobility, entertainment, defence and so on that are of first line importance. There may be many different ways of meeting these needs each with its own costs and benefits. For example, mobility can be provided in a number of ways such as public bus or railway, aircraft, private car, bicycle or walking. Indeed the need for physical mobility may be greatly reduced by the use of electronic media and interactive services requiring very small inputs of energy.

Usually energy contributes significantly and is often vital to these needs but, ultimately, the form it takes and how it contributes is not important to the consumer as long as it actually does the job effectively and is affordable. The way in which demand for energy will develop over the long term is dependent on the way in which the consumers' needs and lifestyles will change. Unfortunately it is extremely complicated and difficult to analyse with any degree of confidence how lifestyles and spending patterns will change. Some work has been done, for example, on the potential impact on energy consumption of a home-based society with intensive use of information. In the OECD countries, an ageing population could suggest a less mobile population with a switch in energy use away from transport and gasoline to domestic heating and natural gas. On the other hand, emphasis on a more active life for the elderly, continuing to work or using leisure intensively, could well lead to much greater use of energy for transport. The subjective judgement involved in these kinds of assessment and the difficulty in relating the results to actual levels and patterns of consumption, are usually such that the practical use of such analyses is very limited.

The chart shows that all the main primary fuels can be, and are, being used

in the industry and domestic markets and for electricity generation. They do not necessarily provide the same type of service or need but they are generally in direct or indirect competition with one another. At present, the transport market is an exception being dominated by oil. The competition from public and private transport using electricity or gas is at present negligible on a global basis. There have been some modest successes in the search for alternatives to oil for road and air travel. However, their current state of development and particularly their cost and ability to meet consumers actual transport wishes seem to present little real challenge to oil's dominance for many years to come.

The structure of energy prices clearly has a major influence on the pattern of fuel use in the markets. This is emphasized particularly where artificial distortions are introduced. In Thailand and Indonesia, for example, through the 1980s price differentials between gasoline, diesel, kerosine and LPG were distorted on social and other grounds. This led to severe shortages of kerosine and LPG, the diversion of kerosine to the transport market to adulterate diesel fuel and widespread smuggling. There are many other examples such as the European subsidies on indigenous coal use, special gas prices to favoured industries, hidden support for electricity from nuclear power. The effect of changes in price differentials on interfuel competition is, however, generally tempered very significantly by the existing structure of the market, the current stock of equipment and consumer preferences related to many factors other than price.

5.1 Electricity Generation

This is the largest single area of demand for primary energy, where all energy sources can be used to provide the same product, electricity. As a result it is also where interfuel competition is often at its most fierce. Consumers want electricity for its convenience and because of its uniqueness and necessity for so many modern needs. Indeed, consumers are willing to pay far more for it than for any other source of energy. In the UK, for example, an equivalent unit of electricity in heat terms would cost a domestic consumer five times the cost of gas oil. Consumers are only concerned whether the electricity comes from nuclear power, fuel oil or whatever if they are sensitive to environmental issues.

The actual mix of fuels for the generation of electricity that evolves in the future will, as in the past, depend on the range and complexity of conditions in individual countries. The type of fuel used for power generation is still in many countries, both industrialized and developing, the result of political decisions based on other than strictly economic grounds.

It is interesting to see the different means of generating electricity in the European Community.

The pattern of fuel use, for what are all well developed and fairly similar industrial societies, is very different. France, for example, generates 75 per cent

of its electricity from nuclear, whilst Denmark generates 90 per cent from coal and Italy some 50 per cent from oil.

Table 11: Share of Fuel in Electricity Generation. Per cent.

	Oil	Gas	Coal	Nuclear	Hydro
Belgium	2.5	8.0	27.3	61.7	0.5
Denmark	5.7	1.4	90.9	-	2.0
France	3.0	0.7	9.2	75.4	11.7
Germany	2.2	7.9	52.0	34.1	3.8
Greece	20.5	0.3	73.6	-	5.6
Italy	49.6	16.6	15.9	-	17.9
Netherlands	4.5	54.7	35.2	5.5	0.1
Portugal	45.6	-	31.1	-	23.3
Spain	6.1	0.8	41.8	38.5	12.8
UK	9.7	0.7	65.1	23.1	1.5

Regional and global issues which may tend toward a uniformity of generation are slowly becoming involved. Concern about the environment already has a stronger influence on the type of fuel and technology used for power generation than in most other markets. The Japanese have for years been using costly LNG and burning high quality crude oil directly in order to alleviate pollution. Gas is finding increasing favour in many countries on environmental grounds. Utilities are also being forced, particularly in the USA and other industrialized countries, to look at alternatives to building new power plants through tariff adjustments and other incentives to consumers to reduce the consumption of electricity by switching to more efficient equipment. Not all environmental measures reduce consumption. The cost of removing sulphur dioxide through the wet scrubbing method results in a 5 to 10 per cent reduction in thermal efficiency.

Certainly the introduction of a carbon tax, global warming or restrictions on nuclear or hydro projects with a cross border effect may well eventually change the overall pattern of generation. The development of international electricity links is set to expand particularly in Europe and South East Asia and these should lead to greater optimization of and significant changes in fuel use. However, with a life time for most power plants of often well over 20 years, the existing pattern of generating capacity extends its influence through the length of most realistic forecasting periods. The strength of views on such matters as nuclear safety, acid rain or the influence of fossil fuel burning on global warming and the need to use

indigenous resources are gradually reflected in government and utility policies. These will play a determining role in the way in which the long-term pattern of electricity generation develops. Technology in the form of high efficiency gas turbines together with growing environmental pressures will favour the greater use of natural gas for electricity generation. The pattern of the fuel mix is, however, still likely to be most strongly related to comparative economics, which may or may not incorporate a measure of some of the global concerns.

5.2 Transport

The demand for personal mobility continues unabated and there is little sign of saturation. Even in the highly motorized USA, which has 560 cars per thousand inhabitants compared with 320 in western Europe and 250 in Japan, the number of kilometres driven per person continues to rise. Unless governments take draconian action through taxes or regulation, car ownership is likely to grow at least in tandem with economic growth. Eventually the cost to the physical and social environment of unrestricted private car use may be seen to outweigh its benefits – but this is still a long way off.

Progress has been made in improving the fuel efficiency of cars and trucks and the average oil consumption per vehicle kilometre has been markedly reduced as a result of the two oil price shocks. In the early 1970s, for example, new US cars averaged 18 litres of gasoline per 100 km. By 1988, this had been halved. There are high fuel economy cars available that could halve this again and prototypes that go even further in squeezing the last drop of effective energy from gasoline. Several countries have already implemented voluntary or mandatory fuel efficiency standards for passenger cars and new cars are steadily increasing in efficiency. Running counter to this is the fact that, throughout the world, vehicle stocks are growing rapidly. Between 1970 and 1987, for example, the number of passenger cars and goods vehicles more than doubled.

Motorization will continue to spread, probably more rapidly than in the past with very substantial growth in the number of vehicles likely in developing countries and eastern Europe. In 1990, markets in the industrialized West accounted for 79 per cent of all vehicle sales and 76 per cent of the world's fleet of vehicles. A recent authoritative report from the motor industry expects that by 2010 over one-third of world sales of vehicles will be in the developing countries, largely in South East Asia. Annual sales volumes in eastern Europe are expected to exceed those of western Europe over the next twenty years.

Although the fuel efficiency of most vehicle fleets has improved steadily, the total distance travelled per vehicle has continued to increase substantially. There has been some reversion to buying larger cars. Future changes to more fuel efficient vehicle technology are now being driven more by environmental considerations than by oil prices. This, particularly stimulated by Californian legislation, is leading to greater effort on the development of genuinely effective

electric vehicles. Any significant impact on the overall vehicle fleet of such alternatives to the tried and trusted internal combustion engine would still seem to be many years away despite the occasional outburst of publicity.

In the industrialized countries of the OECD, as well as in the developing countries, transport activities account for just over one-third of total end-use demand for energy. Particularly remarkable exceptions are the CIS, where only 18 per cent of final energy demand comes from transport and China where the proportion is a mere 7 per cent. Within the transport market, road vehicles are by far the biggest energy consumers, generally accounting for well over 80 per cent of total energy used for transport purposes.

The consumption of diesel fuel for road transport has been increasing faster than gasoline because of substantial increases in the stock of diesel vehicle. This trend seems likely to continue as freight traffic expands, particularly in the developing countries and eastern Europe and its use is further encouraged by fiscal measures.

This is a market that is almost entirely dependent on oil. It is the main outlet for oil and the growth of demand for oil will become increasingly dependent on this single market for transport fuels.

5.3 Industry

There are some problems of definition and reporting on energy used in the industry sector but it is clear that the proportion of final energy demand going to industry is rather less in the industrialized countries of the OECD than in the developing countries. In the CIS over 50 per cent of final market demand appears to go to industry compared with 30 per cent in the OECD and 40 per cent in the developing countries as a whole. Endemic waste, the heavy use of coal, the inclusion of substantial military demand and the underdevelopment of the other sectors accounts for the high proportion going to industry in the CIS.

The pattern and extent of demand for energy by industrial users stems from the mixture of consumer products and the structure and character of the complex and interwoven production network. An underlying influence is exerted by the technology used and the pace at which new methods are adopted. The tendency in industrialized countries is for production to shift away from primary materials to high technology manufacturing. As it does so, the energy intensity measured against monetary value usually falls. In general, countries which industrialized later, such as Japan and more recently South Korea and Taiwan, have been able to benefit from the technological advances made in earlier periods. The faster spread of innovation to industrializing countries is increasingly encouraged by the globalization of many industries and by international programmes to help the transfer of technology. Energy intensity is also being reduced in the industrialized countries through the use of information technology for the control of materials

throughput, the reduction of stocks and wastage and the optimization of energy intensive machinery. In the USA, the amount of fuel used by industry per unit of output has declined by more than 50 per cent during the past twenty years.

These general trends towards less expensive and more efficient technologies and processes in conjunction with changes in the nature of industrial output seem likely to continue to restrain energy growth in the industrial market. In the growing number of newly industrializing countries, such as Thailand and Malaysia, high growth in energy demand might still be expected as they initially concentrate on basic energy intensive industries in the build up of their industrial infrastructure. However, it seems that industrial energy use in these countries may reach lower peaks of intensity at an earlier stage than was the case for previously industrializing countries. This is largely because of the technological advantages of being late into the game.

We would expect all major regions to show relatively slow growth in the industry market over the next couple of decades. Apart from the structural changes to less energy intensive industries and continued improvement in process efficiency there will be the effects of faster penetration of electricity and of gas. These sources of energy are generally favoured for modern industrial processes on the grounds of controllability and cleanliness. Their effective efficiency in application is high compared with most alternatives.

The size and rate of growth of the highly energy intensive chemical industry has a major impact on overall industrial energy demand. In western Europe, 52 per cent of oil products and 22 per cent of electricity used in the industry market are currently for feedstock or process heat used in the production of chemicals. In Thailand, by contrast, only 5 per cent of industry demand for oil is for chemical production. In the more industrialized developing countries, such as Brazil, the proportion of energy used by the chemical industry is not too different to that in Europe, i.e. 53 per cent of oil and 12 per cent of electricity. Not all developing countries will want or be able to develop major chemical industries but the establishment of just one chemical complex can have a significant effect, sometimes doubling demand almost overnight. This is also the case with major iron and steel complexes.

For the more precise and qualitative needs of modern manufacturing processes, electricity and gas seem likely to continue to be favoured sources of energy.

Strong and stable economic growth and a free climate of world trade clearly will be of great benefit in enabling industries in the developing countries and eastern Europe to restructure and incorporate more efficient processes. It will also encourage the movement of industries to cheaper sources of energy and to new regional trading centres such as the Pacific Basin or north-eastern South America. This will, over the next decade or so, be reflected in changes in the regional pattern of energy demand.

5.4 Residential and Services

This tends to be something of a catch-all classification, usually consisting of energy used in private households, in offices and institutions, small businesses and services and often some military and agricultural use.

In the OECD countries, with their heavy heating and cooling load, demand for energy in this sector is usually greater than for industry and about the same as for transport. In the developing countries as a whole, the total amount of energy used for cooking, lighting and heating is much smaller than the demand for transportation or industrial processes. This is partly due to the use of traditional fuels in the household which are not usually recorded and to the absence of a substantial heating load in many countries. None the less, as countries develop and incomes increase, demand by households and services increases in importance. There is great scope for energy savings particularly in the heavy residential heating load of the industrialized countries. Houses and apartments built before the first oil crisis, in a period of low energy prices, with poor insulation apparently still account for 70 to 75 per cent of the total dwelling stock in the OECD. According to some estimates, up to 30 per cent of the energy presently used in space heating could be saved in cost effective ways involving insulation, better heat control and other additional methods. Similar savings could be made in heating and cooling just by better architectural design which integrates with the local climatic and geographical conditions.

Residential use is also affected, particularly in the developing countries, by a number of factors pushing demand upwards, not least increased income and urbanization. A greater use of appliances is also made feasible by the spread of an adequate and assured supply of electricity. Continued low prices for kerosine, gas and electricity in many developing countries also encourage consumption and the replacement of traditional fuels. Smaller households, the use of more efficient fuels such as LPG, more efficient appliances and realistic pricing policies are working in the other direction. Electricity seems likely to continue to penetrate the residential market at above average rates. Appliances, such as very small air conditioners, specially designed for developing country households with modest incomes, are growing in number. Locally-made appliances in many countries have tended to be less efficient than imported appliances used by higher income families. This is changing as more modern designs are being produced. The tendency towards more efficient appliances is probably only partially countered by the growing use of more and larger appliances as incomes increase.

The next two decades or so may see only modest increases in average use per household in the developing countries and perhaps a levelling off in some of the wealthier ones. However, rapidly expanding populations and household formation and increased incomes will ensure that the demand for commercial energy continues to grow, although perhaps more slowly than in other markets.

Much of the growth in energy demand for services is linked with

urbanization and the growth of the bureaucracy. Energy is used mainly in the form of electricity for lighting, air conditioning and heating and power. The intensity of energy use in this market has been falling in many developing countries. This tendency seems likely to continue with the spread of more efficient equipment especially for lighting and air conditioning and the savings available from modern building design.

The demand pattern in all regions is likely to be one of continued substitution of electricity for oil products although with some modest expansion of the combined generation of heat and power by individual enterprises in Europe, Japan and the USA. The spread of gas grids will also ensure a growing penetration of gas for both residential and service use. Where gas grids exist, its higher efficiency over the whole production and supply chain will enable it to stay competitive and to be preferred to electricity.

Agriculture is a key component in the economies of the majority of developing countries although its share of GDP has generally been declining and its share of energy consumed is on average less than 10 per cent of total end-use. In the OECD countries it is even less. The fast growth of energy intensive agriculture that has already taken place in the OECD countries and some developing ones seems likely to continue and spread particularly in eastern Europe, the CIS and China. The impact on agricultural demand for energy could be substantial but not very significant for market demand in total.

Overall, the residential and services market is unlikely to show substantial growth in most of the industrialized countries where a degree of saturation has already been reached and appliance efficiency is improving all the time. A major social change to a home-based, information culture might stimulate some additional demand but it is unlikely to be substantial. In the developing countries, although tempered by increasing efficiency, there is substantial potential for absolute growth as population and incomes rise and aspirations to global standards are fulfilled.

5.5 Overall View

The relative pattern of energy demand that emerges from our quantification, illustrated in some detail in Chapter 6, is one of only slight changes overall between the three main end-use markets over the next twenty years. Industry demand declines as a proportion of total market demand, mainly due to the further move to post industrial societies in the OECD. The transport market increases its share. It is on this latter market that growth in oil demand increasingly depends; well over 60 per cent of incremental demand over the next twenty years stems from the need for transport and mobility.

The fastest growing market for energy in all major regions is electricity generation. Over 50 per cent of incremental demand for energy over the next

twenty years will be from electricity generation.

Overall on a global basis there are no really dramatic winners or losers in interfuel competition. The quantification of the scenarios with one, illustrative, exception indicates demand for all the conventional energy forms increasing over the next twenty years. The use of what is now considered unconventional energy seems unlikely to make significant inroads of global significance over the period covered. In many countries and overall, natural gas continues to gain at the expense of other fuels on environmental, convenience and, increasingly, on cost grounds as availability broadens. Oil retains its near monopoly of the transport market. Coal outlets are largely confined to power generation but even here it increasingly loses out to natural gas as a prime source for electricity generation. Coal remains a main source of energy in only a few countries, notably China.

Electricity demand continues to grow at above average rates as an integral and highly desirable part of modern society. It will continue to be a winner. The pivotal role of electricity generation as the single largest outlet for energy, where almost all sources of energy compete, cannot be overstressed.

One can perhaps say from our look at energy demand in earlier chapters and from the quantification, that seen from the present the world seems unlikely to revert to the levels of growth common in the 1950s and 1960s and earlier. The momentum of existing technology, fuel use and availability and social trends is such that average annual growth in energy demand, for the world as a whole over the next twenty years, is unlikely to be much in excess of that prevalent in the past ten years. It may well be considerably lower.

The period of the 1960s and early 1970s was a golden age of oil demand. The signs now are that the years of the 1990s and the early decades of the next century will increasingly come to be seen as an age of natural gas and electricity.

6 A VIEW OF FUTURE ENERGY DEMAND

6.1 The Building Blocks

The expansion and advancement of economic well-being in conjunction with population growth will remain the fundamental driving forces behind the demand for energy. Thus, a view on the rate of future economic development, allied to a projection of population growth is still the starting point for most projections of energy demand.

One has usually been able to have reasonable confidence in projections of population covering about ten to twenty years ahead. After all, barring global catastrophy, most of the population that will be around then is already living. However, the regional distribution of population is now perhaps less certain than it was because of the possibility of mass migration driven by economic pressures. The effect of AIDS, particularly in Africa, could also turn out to be very dramatic. It has been estimated, for example, that Uganda may have a population of 22 million in the year 2015 compared with 37 million if the epidemic had not taken hold.

Assumptions made on economic growth are usually encapsulated in the form of forecasts for some simple indicators such as GDP or industrial production. Judging by past performance, long-term forecasts of economic development rarely offer grounds for confidence in their accuracy of prediction. However sophisticated the methodology used, the projections are often in practice and, perhaps at best, merely expressions of an informed viewpoint. An added difficulty is that they rarely analyse or describe the changes in society and lifestyles that may lie behind the economic statistics. Such societal changes can often affect the demand for energy much more than the indicated percentage changes in economic indicators.

The developing nature of the relationship of economic growth and population to energy demand and the products and services it meets is also a serious uncertainty and, as shown in earlier chapters, varies widely between countries. Much depends on specific conditions. The resource base, lifestyles, the climate, the existing stock of equipment and vehicles and the pattern of industrial production are significant. These change only slowly over time so that for any type of energy forecasting it is important to have a firm idea of the present situation. Clearly, to forecast the demand for energy by simply relating the growth in energy demand to forecasts of economic growth through energy intensity, whether on a detailed market basis or simple macro relationships, runs the risk of compounding the already large potential for foolish forecasts.

Assumptions on the future development of international and national energy prices are also a part of most demand forecasts. In the past, the projections of the f.o.b. price of international oil associated with demand forecasts have usually been made explicit and, in theory, used as a starting point in quantification. The

way in which they have actually been related to the growth of energy demand in the forecasts is, in practice, often less than clear. Very few published assessments of future demand go beyond international oil prices to the more directly relevant market prices.

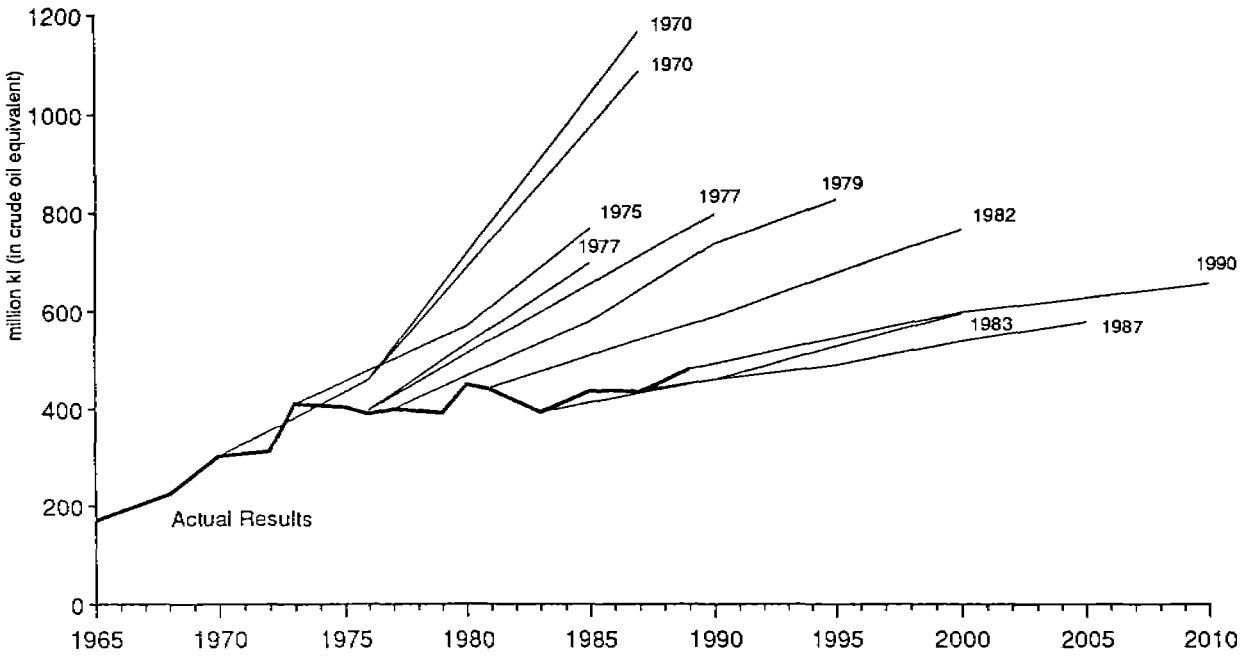
Final demand for oil and energy reacts to factors other than the basic border price of crude oil, coal or whatever energy form. Income changes, taxes, energy policy, consumer preferences and prejudices all encourage changes in overall energy use and in interfuel competition.

In any case, the record on forecasting prices is even more abysmal than for energy demand itself and is unlikely to improve. What is rarely expressed, but which is arguably of more relevance, is the relative value of the individual fuels in their markets. This is something for which there has, at the least, to be an implicit assumption if the changes resulting from interfuel competition are to be foreseen.

The earlier chapters described some of the influences at work on energy intensity and on the pattern and level of energy demand. The successful forecasting of long-term energy demand is fraught with difficulty as will be confirmed by a comparison of almost any past forecast with what actually transpired.

Prior to the 1973 oil crisis the tendency was for each successive new forecast to increase the levels predicted for future demand. This was because actual growth was at such a fast rate that forecasts were continually being left behind by reality. Forecasters were generally not bold enough to accept that growth could continue at such a pace and their forecasts consistently undershot actual demand. The product of this lack of belief was a series of forecasts that always tailed off somewhere in the future. The forecasters were just learning their lesson when the oil crisis came and demand fell. None the less, the forecasters still went on for some years predicting a recovery to a high rate of growth; this time they had to pull their forecasts down every year as expectations were not realized. Again, it took a while before they became bold enough to reduce the forecasts substantially. This effect is illustrated in Chart 4 which shows a number of Japanese long-term outlooks for demand endorsed by the Advisory Committee for Energy compared with actual demand.

CHART 4: Changes in Japanese Long-Term Energy Demand Projections Compared with Actual Results



Source: *Energy in Japan No 105*

The Workshop on Alternative Energy Strategies (WAES) was convened with a panel of distinguished and authoritative people from industry and government to look at alternative energy strategies in the light of high oil prices and supply threats. The results, published in 1977 after two and a half years of collaborative study, as expressed in its most publicized projections were very wide of the actual mark. At the time they were made, however, they represented a fairly acceptable and common view. This had oil demand reaching 58 to 68 million boe/d in the 'World outside communist areas' by 1985 even after allowing for substantial substitution by other sources of energy. In the event actual demand for oil was only 45 million boe/d; total primary energy demand was similarly overestimated. In the 1970s, forecasts continually emphasized the potential for energy shortages and of energy gaps. This was not only for oil but also for coal, gas and uranium. One could produce example after example to show how very difficult it is, when making any kind of forecast, to break away from the accepted wisdom of the moment.

In June of 1991 the OECD/IEA published some projections of global and regional energy demand to the year 2005. These were set against a background of oil prices rising gradually to $35 per barrel by early in the next decade and growth in GDP of 2.7 per cent average annual increase in the OECD and 4.6 per cent in the developing countries. Global energy demand is expected in these projections to grow at 2.2 per cent average annual increase with energy demand growing in the developing countries at 4.2 per cent average annual increase and in the OECD at 1.3 per cent. This seems to be the current consensus view of demand growth; energy demand increasing most rapidly in the developing countries, much more slowly in the OECD at well under the rate of economic growth and at a rate somewhere in between in the CIS and eastern Europe.

6.2 The Next Twenty Years

6.2.1 **Two conventional scenarios**. What assumptions could one now make in order to build an indication of how energy demand might develop over, say, the next twenty years?

That population will continue to increase much faster in the developing countries as a whole than in the OECD countries is, short of a global catastrophe, predetermined. According to the World Bank, there should be an additional 1.7 billion people in the developing countries, including China, by 2010. In the rest of the world population will grow by a relatively modest 0.1 billion. Solely at current per capita levels of commercial energy use, the extra people in the developing countries between now and 2010 would mean some 18 million boe/d additional primary energy demand.

Migration from poorer countries into the richer industrialized countries seems likely to increase under the pressure of population growth. The speed and extent of such migration will depend very much on how well the economies of the developing countries and of the CIS develop and the avoidance of conflict. There would be a marked influence on the regional spread of energy demand and on trade in energy if major shifts in population of this kind were to occur. This effect has not been taken into account in our quantification.

The integration of Europe and the degree of success of common trading areas in North and South America and in the Pacific Basin will also have a profound influence on energy demand over the next twenty years. A more open and successful era of global trading should lead to a less intensive use of energy. This is largely because of the ease and speed with which new and generally more efficient energy using technology would become available and the greater opportunities for investment in the supply of efficient energy sources in a global market. The widespread introduction of mandatory standards or taxation to reduce or change energy use on environmental grounds is probably also likely to be more successful in relation to the extent of prosperity and international harmony.

On the other hand the coming decades could well see an era of inward looking and fragmented economic activity, although perhaps within large trading blocs in some cases. This may fuel a revival of nationalist and isolationist attitudes towards energy. Such self reliance in energy terms is likely to result in the less than optimum use of energy resources and less efficient energy practices. The opportunity for international accord on the environment under these conditions would be limited.

Two broad scenarios thus suggest themselves. First, Scenario A which could be labelled 'Integration and diversity' where international co-operation on trade and the environment continues to expand successfully. Eastern Europe is slowly brought up to western economic standards with steady integration into western economies. The CIS manages to patch together a workable system of economic relations between the independent republics and with the rest of the world. Developing countries debt problems are manageable and new investment sources tapped to enable them to accelerate the process of industrialization. More Taiwans and South Koreas appear, especially in South East Asia and South America but also elsewhere. In general there is an era of co-operation and competition with international action on the environment moving forward successfully and investment flowing relatively freely across borders. This is essentially a scenario of the 'move to the sunlight uplands' type.

As a contrast it is worth looking at future energy demand against a more gloomy, perhaps more realistic, view of the future. In Scenario B, which might be labelled 'More of the same' the world muddles along with some progress in improving per capita incomes. However, the differences between the western industrialized countries, one or two eastern European countries such as Hungary and Czechoslovakia and a handful of prosperous developing regions and the rest increase. South East Asia, India and parts of Latin America make substantial real economic progress and mature politically. Africa, China and much of Latin America, however, remain the poor relations. There is little success in forging a successful market economy in the various constituent parts of the CIS, which are fragmented and strife ridden. Co-operation on the environment rests mainly on intra-regional agreements with little real momentum coming out of any negotiations for international co-operation on climate change; measures to restrict or change patterns of energy consumption are weak and slow in effect.

The perennial problem with such scenarios of the low and high economic growth type is that the results when quantified into energy volumes tend to converge. For higher economic growth the expectation is usually for higher demand growth allied with higher prices but the effect of rapidly increasing demand is to encourage faster change to more energy efficient technologies. Higher economic growth, with or without higher prices, leads to technical innovation and improvements in energy use. These mitigate much of the cost of energy which may have been increasing. Thus, the intensity of energy use may fall at a faster rate than in a less buoyant economy. Lower economic growth and activity, on the other hand, usually reduces energy demand and price expectations which delays

the introduction of new methods and technology. As a result, energy intensities do not move very rapidly and may even increase. Thus there tends to be a long-term closing of demand estimates around a fairly narrow range whichever economic growth rate is postulated.

In both of the scenarios quantified, the long-term influences on interfuel competition of consumer preferences, environmental legislation, government pricing policies and other elements covered earlier, have been viewed in the light of relative long-term cost relationships and supply availabilities. These relative costs and the potential supply position have been based on those developed in earlier OIES Reviews of Energy Costs and of Long-Term Energy Supplies.

On the basis of comparative economic costs alone a fairly conventional pattern of energy usage and supply will persist well into the next century. At present and for some time to come, the most cost competitive alternatives to oil are not those that could replace conventional oil in the road fuels market. The cost effective alternatives such as low cost coal, liquefied and pipeline gas and Orimulsion will largely affect the demand for gasoil and fuel oil. There would seem to be little justification either on cost or physical supply grounds for widespread use of non-conventional energy sources or technologies.

International oil prices under both scenarios are assumed to be much more a product of the way the world develops than actually influencing that development. Under both scenarios one might expect continued loosening of the ties between gas and oil prices. The greater competition and investment opportunities under Scenario A should mean a relatively easy supply position for energy, at least through the 1990s. Thereafter, the climate for investment and the physical potential would seem to provide the ability to overcome any problems presented by substantial calls for incremental energy. Given a growing interchangeability of energy sources, oil prices in real terms will at best remain level through the 1990s although they may well be tightening by the early part of the next century. Energy-importing countries seem likely to allow only a partial pass through of any decline in prices to consumers in order to encourage savings.

Scenario B, with social and economic difficulties in many parts of the world, may result in a tighter and more uncertain supply position. The supply of oil outside the Gulf may peak earlier than under the Scenario A because of a lack of investor confidence and there could be some upward pressure on oil and energy prices towards the end of the 1990s. At any time, under both scenarios, there are likely to be future short-term price shocks although growing supply flexibility should reduce their length and impact.

The projections of economic growth assumed for the quantification of the two scenarios are set out in Table 12 along with those for population. It should be stressed that the GDP growth rates indicated are not the result of any deep analysis but are merely a representation of two different views of possible growth.

Table 12: Demographic and Economic Projections

	1990	2010
Population (billion)		
OECD	0.9	0.9
Developing countries	2.9	4.4
China	1.1	1.4
E.Europe	0.1	0.1
CIS	0.3	0.3
Total	5.3	7.1
GDP Growth Rates		
Annual average growth rates(%) 1990 to 2010		
	Sc A	Sc B
OECD	3.0	2.0
Developing countries	5.5	3.0
China	6.0	3.5
E.Europe	3.0	1.0
CIS	2.0	0.7
Total	3.6	2.0

The two scenarios briefly described above are, of course, just two of the many economic and political paths along which the world may develop over the next decades. They have been used solely as an illustrative basis from which to quantify potential levels of future energy demand. The actual process of quantification has been based on assumptions in line with those expressed earlier on the changing relationship between economic growth and energy demand, on structural changes in the energy market and on the potential for substitution between fuels at different price levels and policy regimes.

Some of the key results are shown below:

Table 13a: World Primary Energy Demand. Million Barrels of Oil Equivalent per Day.

Scenario A (Integration and diversity)

	1990	2000	2010
Oil	63.4	73.6	83.7
Coal	44.6	48.4	48.1
Natural Gas	35.3	45.3	59.5
Nuclear	9.4	11.8	16.5
Hydro etc.	12.3	15.1	20.9
Total	165.0	194.2	228.7

Scenario B (More of the same)

Oil		70.4	76.3
Coal		48.9	47.7
Natural Gas		40.4	49.6
Nuclear		11.4	13.4
Hydro etc.		13.9	18.5
Total		185.0	205.5

Table 13b: Regional Distribution of Demand. Million Barrels of Oil Equivalent per Day.

	1990	2010	
Primary energy		Sc A	Sc B
OECD	85.1	101.2	97.3
Developing countries	31.0	60.4	50.7
CIS	27.5	32.5	29.2
E. Europe	7.6	10.1	8.4
China	13.8	24.5	19.9
Total	165.0	228.7	205.5
Oil			
OECD	35.8	41.8	39.6
Developing countries	14.8	26.0	23.2
CIS	8.2	8.6	7.2
E.Europe	2.2	3.0	2.6
China	2.4	4.3	3.7
Total	63.4	83.7	76.3

Table 13c: Market Demand. Million Barrels of Oil Equivalent per Day.

	1990	2000	2010
Scenario A			
Transport	30.8	37.2	42.5
Industry	39.1	42.9	45.6
Residential/Services	33.1	37.3	40.6
Total	103.0	117.4	128.7
Electricity generation	58.5	73.9	97.6
Scenario B			
Transport		35.7	39.4
Industry		41.7	44.2
Residential/Services		36.1	37.2
Total		113.5	120.8
Electricity generation		68.1	81.5

The results indicate demand for primary energy under Scenario A growing at an annual average of 1.6 per cent compared with 1.1 per cent under Scenario B. This compares with an average growth in world energy demand over the last twenty years of 2.3 per cent.

The closeness of the results in volumetric terms is remarkable but not unexpected. As mentioned earlier, the favourable conditions for investment and trade of Scenario A lead to much greater technological application and the optimization of energy use which temper the effects of higher economic growth on energy demand. The more inhibited and restrained global economy of Scenario B hampers investment in new plant and technology. As a result, the intensity of energy use is higher than under A.

Energy intensity falls between 1990 and 2010 under Scenario A by some 30 per cent which is well over double the rate of the last ten years. Under Scenario B it falls by just under 20 per cent in twenty years. The momentum for innovation in the more efficient use of energy is kept up under both scenarios and is partly encouraged by growing environmental fears. However, the rapid growth in fuel demand for electricity generation tends to partially counter the savings brought about by increased efficiency in end-use applications.

The share of demand met by oil and coal decreases under both scenarios and that of natural gas increases. The level of demand indicated for gas in the year 2010 under Scenario A represents a formidable challenge in putting in place the necessary supply infrastructure and trading arrangements. The volume involved, some 3300 bcm, does not, however, represent a potential supply constraint position in itself and should not cause a significant increase in international gas prices.

Global oil demand under Scenario A reaches some 84 million boe/d by 2010 and 76 million boe/d under Scenario B by the year 2010. Demand is driven largely by substantial growth in road transport in the developing countries and in the CIS. Outside the transport markets, oil is increasingly displaced by gas and electricity.

The demand for oil under Scenario A particularly is above the supply potential for conventional oil currently projected by some authorities. Much depends on the view taken of the possible level of non-OPEC production and the willingness of consumers to rely heavily on oil supplies from the Gulf. In a previous OIES Review a country-by-country analysis indicated that supplies from non-OPEC sources including the CIS and China could still be maintained at current levels of around 40 million boe/d in 2010, given favourable investment conditions. This would, in the case of Scenario A, still require nearly 45 million boe/d of oil to be found from elsewhere. Not all of this will need to come from those countries which are now members of OPEC. Some of the additional oil could come from unconventional sources or from greater substitution by natural gas and renewables than we have considered. It does, however, make a significant contrast

with the present call for some 23 to 24 million boe/d from OPEC sources.

Clearly the call on Gulf oil will increase substantially unless very rapid progress is made in lowering the cost of unconventional oil from gas and other sources, or unless the world is underestimating the potential outside the Gulf region. Such underestimation has occurred on a consistent basis for many years and we may still be in for some surprises on the volumes of oil that can actually be supplied. The prospect of a tightening oil supply position could also concentrate the minds of governments on the greater encouragement of savings and substitution.

Solely on the basis of resources available, the increased call on Gulf oil under the scenarios should not be a limiting factor. Even if politically acceptable it would, however, at the least indicate a tightening of oil prices at the turn of the century. As the bulk of the additional oil would need to move to developing countries, there could be a major impact on overall global development by the turn of the century.

The general picture that emerges from the quantification of the two chosen scenarios remains a fairly conventional one in terms of the long-term growth in energy demand and the call for oil. The tendencies and patterns of demand that we have indicated for the future could well prove to have been accurate as the years progress. However, to be realistic, the actual volumes may easily turn out to be significantly out of line with what is actually demanded. On past form, it is very likely that today's reasonable and acceptable view of the future will eventually come to be seen as hopelessly wrong.

6.2.2 **A different view.** The growth of future global demand for energy could well be rather less than indicated by our conventional scenarios. It could also be much more.

The feasibility of sustainable development, with modest or nil growth in energy demand, has been well argued by a number of authorities. It does not necessarily have to be based on environmental concern; from estimates by Amory Lovins and others, it seems to make sound economic sense for governments, utilities and others to positively encourage the use by consumers of the latest efficient technology. However, this does not appear to be occurring at present on any significant scale; there does seem to be a need for a much greater stimulus. If, say, the United Nations Conference on Environment and Development or subsequent international accords on the environment do act as the necessary catalyst, then one could envisage a substantial change in attitudes to energy use which should lead to considerably lower demand.

To make a significant impact within the next twenty years there would probably need to be deep government intervention and large transfers of wealth and technology between countries. As discussed earlier in this review, modern

energy using technology is generally more energy efficient and substantial savings are already built into most projections of energy demand. Much more positive action has to be assumed if less energy is to be used than the volumes that emerge from the two conventional scenarios. A reliance on normal rates of equipment turnover and changes in practice and structure in line with those of the 1970s and early 1980s is not enough.

If one assumes some kind of global drive, which at the moment only a real fear of global warming seems at all likely to trigger, it would be directed on a number of fronts.

In order to constrain demand substantially, improved energy efficiency in use could be induced through a combination of an environmental tax, regulation or some other kind of incentive. Higher costs and prices would reduce the demand for a particular fuel or number of fuels compared with what it might have been. Although, by how much a particular increase in prices would actually reduce demand is not clear, despite many past attempts to model the effects.

There would also be a technological and management response. Combined cycle gas-fired power plants as well as fluidized bed combustion would be introduced at an accelerated rate through measures over and above the existing economic incentives. The introduction of combined heat and power, mandatory fuel consumption ratings and sizes for cars, high efficiency lighting, improved insulation in homes and commercial buildings and so on would all have to be encouraged by changes in pricing policies and tax structures. The free flow of information and technology and managerial expertise would be a necessity; as would the provision of substantial amounts of capital for the accelerated replacement of existing equipment.

On the supply side, solar power, hydro and the introduction of super electricity grids to optimize electricity generation would be widely supported through the focussing of investment and research funds and fiscal policy. Perhaps genuinely renewable and environmentally friendly uses of biomass could also be developed on a wide scale over the next twenty years or so.

The position of nuclear power in any environmentally driven future is ambiguous. The use of nuclear is, of course, highly beneficial in reducing global CO_2 levels. There are, however, other substantial potential dangers to the environment from the whole nuclear cycle which are still very much a public and international concern. New 'safe' and economic nuclear technologies may well be developed and become acceptable. It seems at present unlikely, although not impossible, that any revival in nuclear power could be sufficiently early to have a major impact within the next two decades.

More significantly, with gas probably the main supply leg of any successful environmental scenario, investment funds would have to be readily available on an international basis to finance new export and distribution projects. Those

countries with little option than to continue to rely on coal, such as China, would have to be helped to introduce coal washing facilities and more efficient transportation and application technologies. In most countries, however, coal seems likely to lose market share over the long term as will fuel oil and to some extent middle distillates.

In addition to measures for reducing energy demand and changing the pattern of supply, it seems likely that action would need to be taken to change the overall pattern of economic activity. Greater recycling, the use of less mechanical and chemical based agricultural practices and, not least, the restriction of the motor car should all play a part. All require substantial and farseeing political commitment.

Clearly much of the foregoing is somewhat idealistic and for the most part may prove impractical given an innate inertia, the necessary capital and the unprecedented degree of international harmony and political agreement required. The overall cost benefit of these actions and particularly of one fuel versus another, is also not clear or fully accepted.

In practice, the kind and style of economic growth under such a scenario would be different from that under the two conventional scenarios so that the usual measurements of economic growth are probably inadequate. None the less, for illustrative purposes we have assumed a growth in GDP, and in population, in line with that of Scenario A. To make any significant impact on global energy use, that is to restrain overall growth in energy demand to well under 1 per cent average annual increase, energy intensity would need to fall by more than half. This can be achieved by making bold assumptions on the impact of structural change, faster introduction of more efficient technology and substantial changes in the fuel mix. There is scope to achieve this kind of reduction in the CIS and China although it stretches the imagination somewhat to envisage OECD intensity falling to well under 2 boe per $1,000 of GDP from the present 3 boe.

Total primary energy demand under this simple illustrative Scenario E, remains roughly at the same level in 2010 as it is at present for the OECD as well as for the CIS and eastern Europe. It is, however, difficult to see how energy growth in China and the developing countries could be restrained very much below 1.5 per cent average annual increase, given the degree of industrialization and motorization needed to sustain the economic levels assumed for substantially increasing populations.

Although end-use electricity demand overall in this scenario grows more rapidly than under Scenario A, the amount of energy used for its generation is less. This is due to the wider use of more efficient plant and solar photovoltaics towards the end of the period. Much reliance has, perforce, to be placed on natural gas but the improvement in end-use efficiencies and the reduction in transmission losses keep the global call for gas to fairly manageable levels. Nevertheless, international trade in gas would need to quadruple by 2010. The impact on coal

producers and the international trade in coal would be dramatic. The demand for coal falls under this Scenario by 40 per cent, with the most substantial decline occurring in the CIS. In this scenario, global oil demand is lower in 2010 than at present, just under 60 million boe/d. Assuming the same levels of non-OPEC oil production as in Scenario A, the call for oil from the present OPEC states would remain close to present levels if not slightly lower. Oil demand is concentrated in the transport sector with some modest growth in developing countries in other sectors. However, there should be some compensation for lost revenues from the additional demand for gas, much of which will have to come from the traditional oil exporters.

Low oil and other energy prices, if allowed to pass through to the consumer, would eventually bring about upward pressure on oil demand although these dynamics have been ignored for the purposes of the quantification.

In contrast to this kind of scenario, it is possible to imagine a world where growth in energy demand could move back towards the rates common in the 1950s and 1960s. The present climate is against it but there are signs of a slackening off in the willingness to restrain consumption. Large cars are now being heavily marketed again in the USA and there are governments who do not accept the link between energy use and global warming. Even if they do accept it, they do not necessarily consider the overall effects harmful and may even consider them beneficial.

In a world of, say, more inward looking national groupings, coal would continue to be used on a substantial scale as a major source of indigenous energy. Growth in the use of natural gas would be slow in eastern Europe and the developing countries and the development and application of new technologies slowed. Pricing and tariff policies would continue to favour uneconomic energy forms in a number of countries and subsidies maintain profligate energy use. In the CIS, economic and political stress would prevent effective measures to curtail waste in energy use.

This scenario assumes that energy intensity in the OECD improves at a rate only half that of recent years and for the developing countries continues to increase in the 1990s but, thereafter, to fall back to the current level results. The result is growth in global demand for energy increasing at 3.2 per cent average annual increase to 2010. Within this overall growth rate, demand in the OECD grows at 2.6 per cent average annual increase and in the developing countries at 5.4 per cent average annual increase.

Growth rates such as these would bring demand up against supply constraints by the turn of the century. Balancing largely on oil, the call for oil from the present OPEC states would be nearly 90 million boe/d. Clearly, before these constraints are reached prices would rise and indirect and direct effects reduce demand. However, solely as an illustration of the levels of energy that would be needed, we show this scenario, labelled G, without any feedback effects.

A comparison of primary energy demand in 2010 for all four scenarios is shown below:

Table 14: World Primary Energy Demand in 2010. Million Barrels of Oil Equivalent per Day.

	Scenario			
	A	B	(E	G)
Oil	84	76	(59	128)
Coal	48	48	(28	73)
Natural Gas	60	50	(60	65)
Hydro, nuclear etc.	37	32	(37	40)
Total	229	206	(184	306)

In the words of the old horse-racing adage 'you pay your money and you take your choice'. However, the above comparison does illustrate the enormous range of potential demand. More importantly it reinforces the fundamental need for flexibility in planning to meet that demand.

Appendix 1

ENERGY POLICY

The future structure of the international energy market and the overall pattern of energy use will continue to be strongly affected by national conditions and aspirations and the changes in relative strengths of individual countries. These may be reflected in and influenced by national energy policies whether stated or unstated.

In recent years and certainly over the coming decades, the influences on demand for energy have become more internationalized. The level and pattern of energy demand in individual countries is increasingly influenced by international and inter-regional policies and agreements. These may be related to broad economic and trade fields and to the environment through the EC, ASEAN, North American Free Trade Agreement, CNC agreement and so on. They may lead on, for example, to the harmonization of prices, open access to transmission systems, free flow of capital, the encouragement of privatization and the development of new industrial processes. All of which can significantly affect energy demand even where not specifically designed to do so. The influence of international policies and agreements on the pattern of energy demand seems likely to become greater and occur at a faster pace in future.

Since the early 1970s government policy, effort and taxpayers' money in many countries has been directed towards encouraging savings in energy consumption and the use of alternatives to oil. Alternatives to oil have ranged from supporting the use of small-scale localized renewable energy sources to the development of nuclear electricity on a substantial and centralized basis. Many of these measures do not affect the overall demand for energy directly, although they may eventually change the pattern of use. The very substantial and rapid development of the French nuclear programme in excess of 'normal' demand growth led to strong official campaigns to use more electricity with a consequent effect on demand for fossil fuels.

Changes in policy on supply of energy do clearly affect the overall levels of demand but usually only in a fairly moderate way. Exceptions are where there is a major change from an inefficient energy source to an efficient one. The change from towns gas manufactured inefficiently from coal and oil to the direct use of natural gas that took place in the 1960s in a number of European countries, reduced the level of demand for primary energy well below what it would otherwise have been. Any future change in eastern Europe from using lignite in industrial and residential markets to using natural gas or oil products should result in significant falls in energy intensity and possibly in overall demand.

In the past, national policies on energy supply have generally aimed at

ensuring security of supply or reducing import bills. In many developing countries it has also been used, not always successfully, to provide affordable energy for low income sections of the community or to direct energy to where it appears most needed.

The perceived need for security of supply as well as social and political pressures have helped to maintain the use of indigenous coal in meeting demand in a number of European countries long after more economic and efficient alternatives have become available and viable. There is now a growing unwillingness to subsidize indigenous coal in western Europe and its use in, for example, Germany, the UK, Spain and Greece seems likely to decline rapidly over the next few years. This should only marginally affect the amount of energy directly consumed by markets. There should, however, be a reduction in the amount of primary energy demanded because of the elimination of the substantial own use of energy by the coal industry itself. In a few countries such as China it seems likely that coal will remain the major part of the energy economy well into the next century. Better preparation at the mine, more efficient transport and use, could none the less greatly reduce the tonnages actually required and slow down the growth in primary energy demand.

Although most of the OECD countries have attempted over many years to encourage renewable alternatives to fossil fuels such as wind, solar power and biomass, the impact on patterns of demand has been negligible. A major change could occur if on-site energy production were to become economically and socially attractive. The ability to have energy at the point of use under the direct control of the consumer would change significantly the way in which energy was used and reduce the volumes demanded. Substantial savings could be achieved in reducing the transmission and distribution losses that are inevitable in supplying energy from centralized sources. A halving of electricity transmission and distribution losses if production were to be concentrated at the point of use would, in the OECD alone, result in half a million boe/d less energy being required.

If, for example, the next few years were to see a genuine cost breakthrough in the cost of photovoltaics then demand patterns in the residential and services market would certainly change. There may well be other technology waiting in the wings, such as safely packaged isotopes, but their impact is unlikely to be felt within any sensible forecasting period. The time needed for market penetration together with the weight of existing equipment ensures that a significant impact on the present broad pattern of conventional fuels is unlikely before well into the next century.

The emphasis of energy policy over the next twenty years or so is, in the industrialized countries at least, likely to be driven much more by the need to reduce the environmental impact of energy use. In conjunction, as part of the move to large economic trading groups, will be the desire to make the supply system and the markets more open to general access. These latter developments can only help the optimization of energy use and dampen physical demand.

The introduction of discriminatory taxes to discourage the use of polluting fuels will clearly affect demand patterns. A carbon tax on the lines proposed by the EC could well push gas demand to its supply limits in the short to medium term. The nettle of reducing urban congestion by, say, discriminatory pricing of vehicle journeys on the Singapore model, may one day have to be grasped. This will obviously affect the demand for gasoline and diesel fuel as will continued pressure on car manufacturers to produce more efficient vehicles. Even with continuing low energy prices, the environmental pressures seem strong enough to ensure that the general ethos of energy saving remains through the coming decades. Thus, one could expect the efficiency of energy use to continue to improve at least at past rates. The actual rate at which efficiency improves will be very dependent on the rate of overall economic growth and of technological transfer, particularly to eastern Europe and the developing countries.

The USA currently accounts for nearly 25 per cent of the world's demand for energy, more than the whole of western Europe or the CIS. As such, the direction of US energy policy is highly relevant in any assessment of future demand levels. The most recently published expression of US energy policy is the National Energy Strategy released in February 1991. This puts its most positive emphasis on energy supply but does contain some proposals for reducing energy use, particularly of oil. The expressed aim is to keep growth in primary energy demand to an annual average increase of around 1 per cent to the year 2010. This is unlikely to be difficult to achieve considering that primary energy demand in the USA has been growing at less than 1 per cent over the last ten years. In practice, the measures indicated are very weak and do not involve increasing taxes on gasoline, which are at present low in comparison with Europe or Japan. None the less, most of the 'savings' expected in oil use are to be obtained by reducing consumption in motor vehicles. This is to be achieved partly by substituting other fuels and partly by improved fuel efficiency. In other markets than transport, the potential savings indicated are very small and are expected to be achieved by fairly soft methods such as encouraging research and development.

The main approach to electricity generation and use is to alter Federal and State regulation of the electricity industry to allow more competition and efficiency. There is also some support for integrated resource planning which compares the value of electricity demand reduction options with those for additional supply. This could be the most fertile route for reducing energy demand through the encouragement of more efficient lighting and equipment and the optimal use of electricity. The strategy is short on obvious direct methods of affecting demand. It does, however, have the merit of neither seeking to increase regulations and controls on the energy industry and consumer, nor wanting to expand the bureaucracy and the resultant opportunities for syphoning off the taxpayers' money. In addition, it avoids setting out the kind of detailed strategy based on firm views of the future that has been made to look so ludicrous in the past.

The US National Energy Strategy is unlikely by itself to change the

appearance of the energy market or influence significantly the level of energy demand over the next twenty years. Clearly, individual state initiatives – particularly on motor fuels in California – will affect demand fairly specifically and be imitated elsewhere. The reduction in fuel use is in practice difficult to determine as there are counter-effects such as greater mileage and bigger cars. Pressure to reduce vehicle emissions and the steady introduction of new fuel efficient technologies will continue in the USA and its influence in these fields on the rest of the OECD will be strong.

Most western European countries if they have an energy policy at all usually encourage conservation through financial and other incentives to raise insulation standards and increase appliance efficiency. The European Charter, which has yet to be adopted, has the objective of promoting the construction of a Europe-wide market for energy. Most of the emphasis is on the expansion of trade and co-operation in energy with eastern Europe, and supply issues also loom large. The proposals for expansion of gas networks on an open basis, for the modernization of power stations and grids and of refineries could, if successful, change the pattern of demand in eastern Europe within a decade or two. Economic growth could be thus supported without the need for substantial increments of energy. The danger with many of the detailed proposals is that they could easily lead to the introduction of more regulations, unnecessary standardization and centralized control. Detailed intervention, particularly where there are specific politically driven pressures on the use of one energy form as opposed to another, could distort the market and act as a damper on the investment needed to reduce the intensity of energy use in eastern Europe.

Consistent efforts since the early 1970s in conservation and efficiency, particularly in industry, have made Japan one of the most energy efficient countries in the world. Reviews of policy on energy are usually accompanied by detailed estimates of future demand and supply levels. These, as with most such estimates, are swiftly overtaken by events but in any case are usually more in the nature of flexible targets than the forecasts that they may actually be presented as. They may also be used for the manipulation of potential energy suppliers.

The most recent revision of the long-term outlook from the Advisory Board to the MITI minister was developed against a background of demand reverting to growth levels close to those of GDP. There was also a growing awareness of the need to take environmental issues seriously and a need to look again at the dynamic Japanese nuclear programme. As a country poorly endowed with natural resources, Japan has long stressed the implementation of energy conservation measures and the need to encourage renewables through a variety of programmes. The long-term outlook of 1990 calls for a 36 per cent reduction in energy consumption per unit of GNP over the period to 2010. This is roughly what was achieved over the 15-year period from 1973 to 1988 during which two oil crises were experienced. This would mean a ratio of growth in energy demand to growth in GNP of well under 0.5 per cent. Much of the past improvement in energy use has been through efficiency gains in industry as a result of better management

practices and major investments in new, more efficient equipment. Changes in the industrial structure, with shifts to less energy intensive industries such as electronics and machinery, have also helped. However, progress in energy conservation in industry is becoming more difficult to achieve; additional investments tend to be much more costly and changed patterns of demand due to changing lifestyles limit further improvements of unit energy consumption per product. In future, there will have to be heavier reliance on the wider introduction of insulation in buildings and the improvement of efficiency in vehicles and power generation in future. Today's fuel efficiency of cars is about 30 per cent better than in the early 1970s, but average fuel consumption started to increase again in 1982 and consumers have a growing preference for larger better equipped cars. This, with growing traffic congestion, is having a distinct effect on fuel consumption in the transport market. On the environment, there is a policy objective of reducing CO_2 emissions to a rate of increase of 1 per cent per annum to 2005, to be followed by a decline at the rate of 0.1 per cent per annum. This is supposed to be achieved partly by energy conservation but also by an increased supply of non-fossil energy sources. In reality, the overwhelming source of these non-fossil fuels will continue to be nuclear power.

If the stated policy is successful, then one might expect an overall growth of primary energy demand in Japan over the next twenty years of around 1.5 per cent per annum on average. Within this growth, the pattern of fuel use will alter. Natural gas, as well as nuclear, will increase its share in power generation. Gas will also take up a bigger share in the residential and commercial markets. Part of the increase in these latter markets will come from an expansion of co-generation systems, perhaps including fuel cells, which should help to improve overall efficiency. Oil use should grow significantly only in the transport market. As with other advanced countries, structural changes will continue to reduce industry's share of energy demand and increase the share of the residential and services market.

Appendix 2

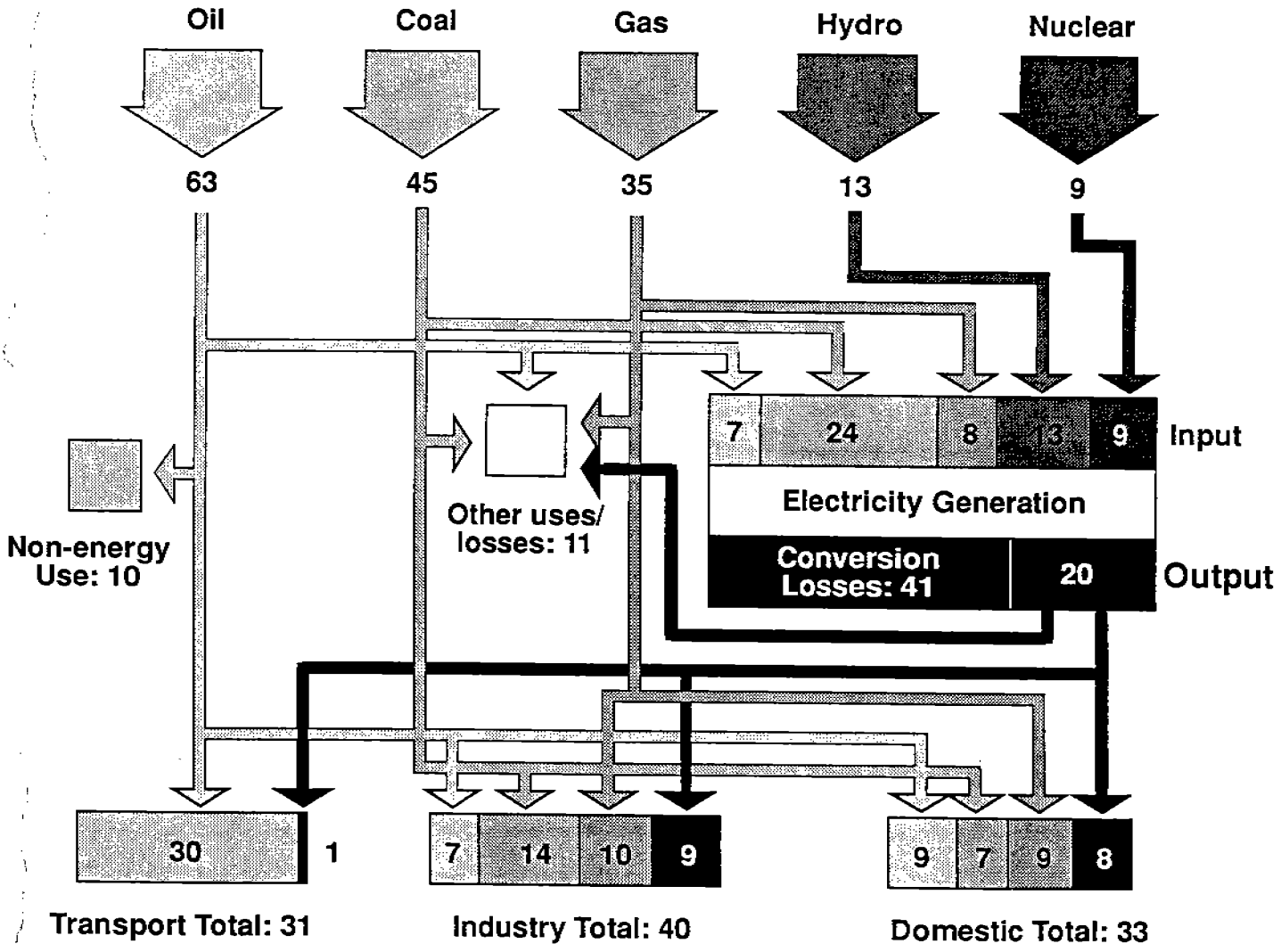
Abbreviations and units

CIS	The republics that made up the old USSR
OECD	Organization for Economic Cooperation and Development
S. Asia	South Asia. Largely India, Pakistan and Sri Lanka
S.E. Asia	South East Asia
boe	barrels of oil equivalent (5.8 million British thermal units, 5.7 Gigajoules)
boe/d	barrels of oil equivalent per day (50 toe)
b/d	barrels per day
bcm	billion cubic metres (17,800 boe/d)

5 INTERFUEL COMPETITION AND THE MARKETS. WINNERS AND LOSERS?

Chart 3 illustrates in a simple schematic form the flow of commercial energy for the world as a whole in 1990.

CHART 3: The Flow of Energy, the World, 1990
Million barrels of oil equivalent per day



The chart shows along the bottom the physical volumes of energy actually demanded by consumers in the main end-use markets in 1990. This market demand, of some 104 million boe/d, represents only 63 per cent of the total amount of primary energy that has to be supplied. The proportion naturally varies from country to country depending on the supply structure, fuel mix and economic

CHART 1: World Commercial Energy Demand 1920–90

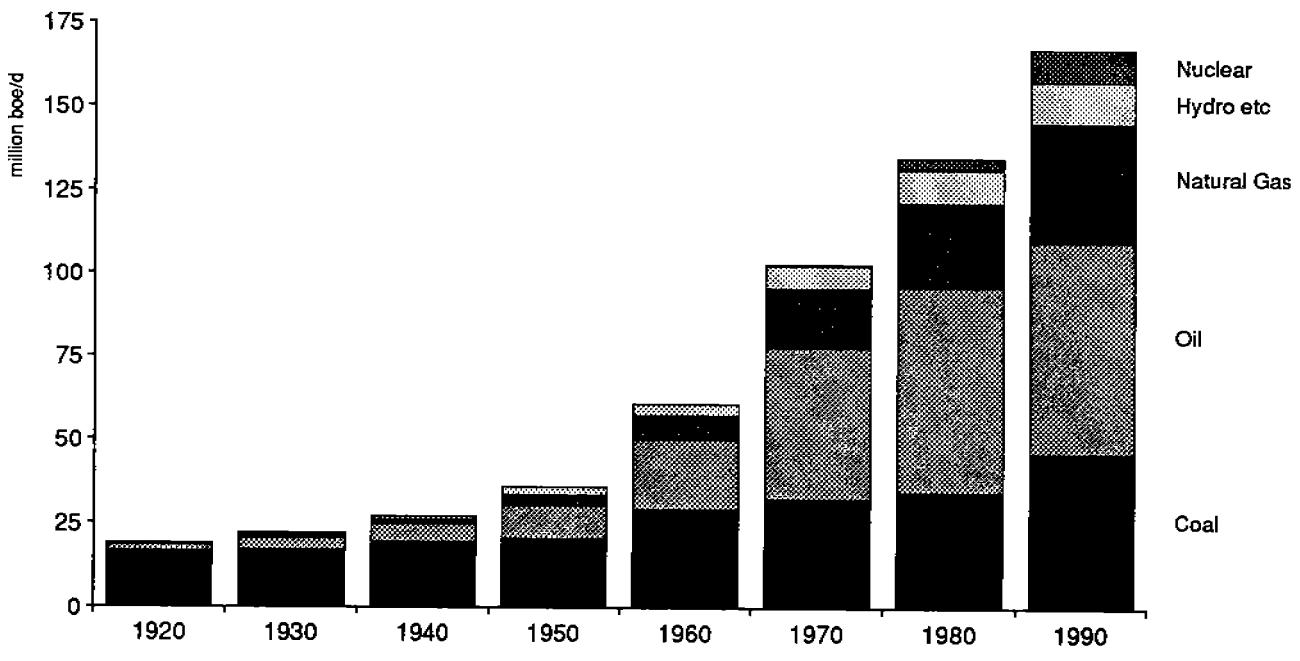
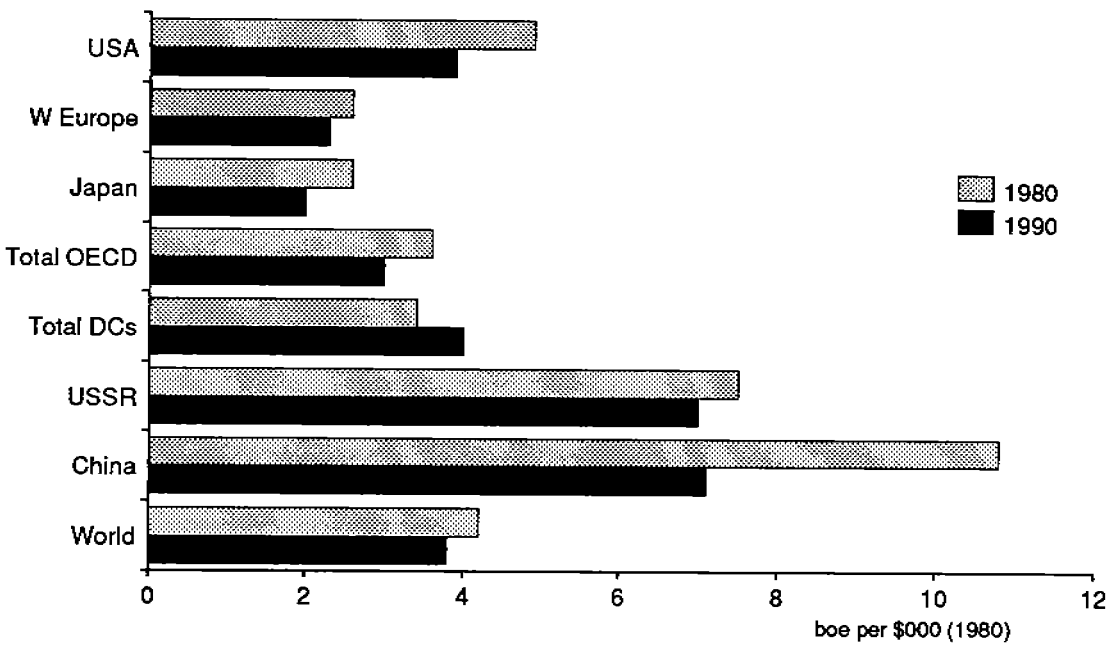


CHART 2: Intensity of Energy Use, 1980 and 1990



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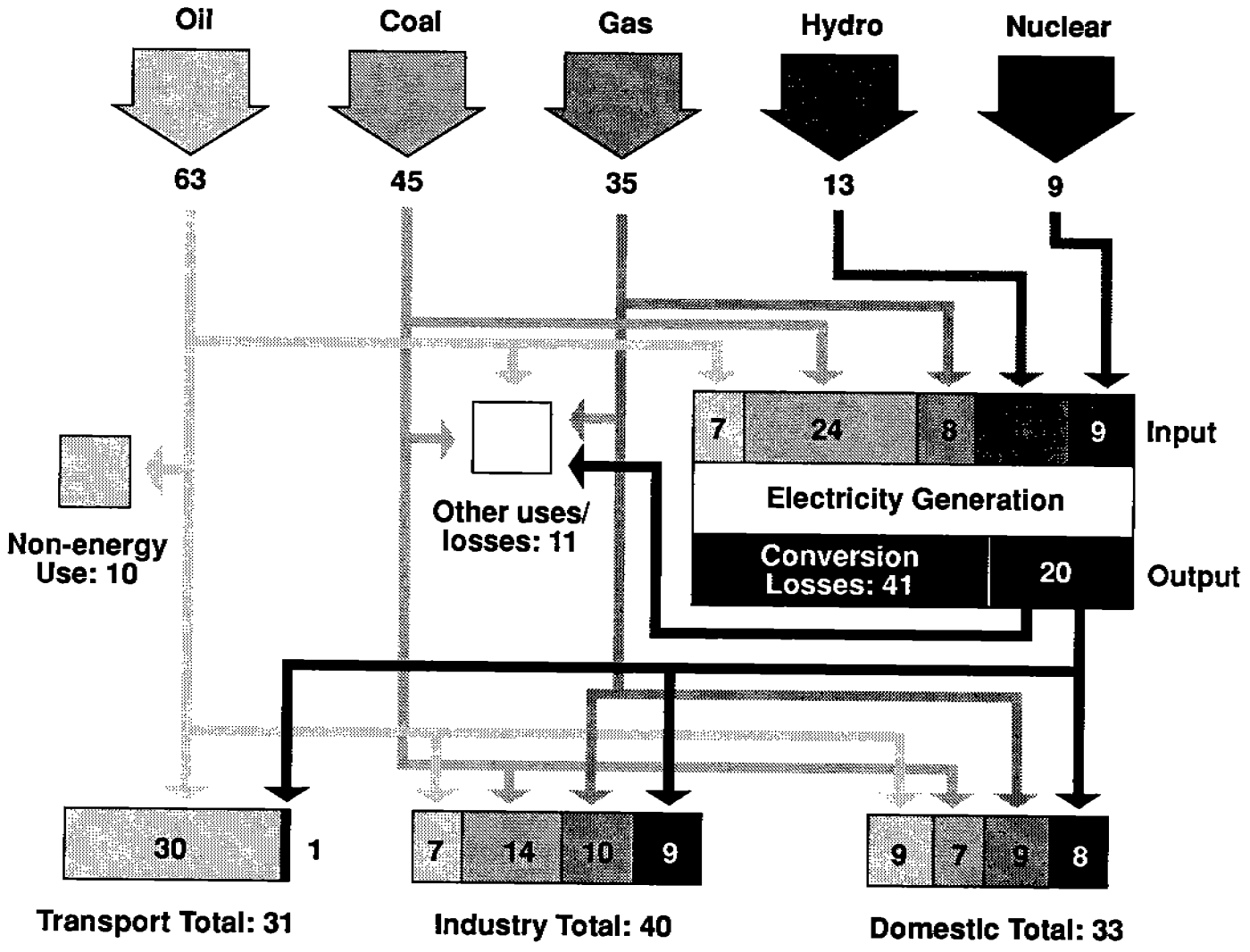
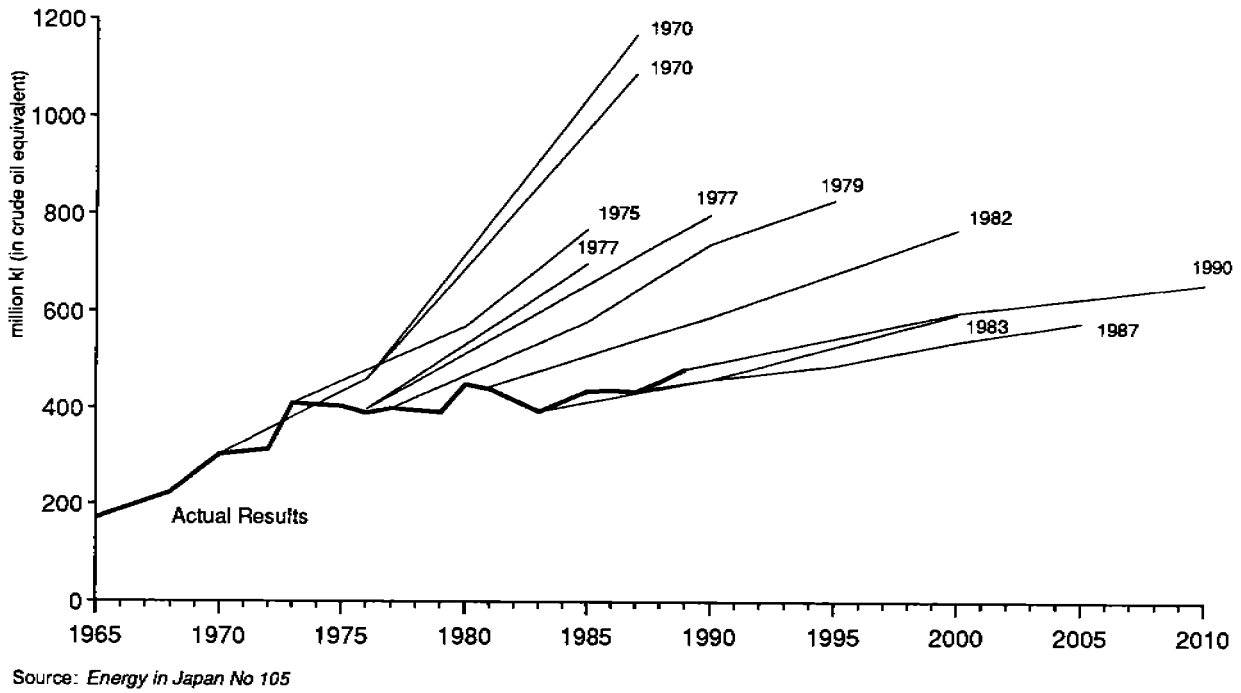


CHART 4: Changes in Japanese Long-Term Energy Demand Projections Compared with Actual Results



Source: *Energy in Japan No 105*

(Chart 4)

The Workshop on Alternative Energy Strategies (WAES) was convened with a panel of distinguished and authoritative people from industry and government to look at alternative energy strategies in the light of high oil prices and supply threats. The results, published in 1977 after two and a half years of collaborative study, as expressed in its most publicized projections were very wide of the actual mark. At the time they were made, however, they represented a fairly acceptable and common view. This had oil demand reaching 58 to 68 million boe/d in the 'World outside communist areas' by 1985 even after allowing for substantial substitution by other sources of energy. In the event actual demand for oil was only 45 million boe/d; total primary energy demand was similarly overestimated. In the 1970s, forecasts continually emphasized the potential for energy shortages and of energy gaps. This was not only for oil but also for coal, gas and uranium. One could produce example after example to show how very difficult it is, when making any kind of forecast, to break away from the accepted wisdom of the moment.

Bank projections but with no increase in per capita consumption, demand for energy in the developing world including China would increase by 17 million boe/d over the next twenty years. Thus, the expanding population of the developing countries, without any increase in energy needed per head or in absolute demand in the developed countries, could result in a future increase in world demand for energy of around 0.5 per cent per annum. In practice, short of a global catastrophe, it is unlikely that per capita consumption in the developing countries will actually remain at current levels.

3.2 Intensity of Energy Use in Relation to Income

There are also considerable differences amongst countries in the intensity of energy use in relation to economic and physical output. An overall intensity of energy use is often represented in broad terms by the amount of commercial energy consumed in relation to GDP.

(Chart 2)

A striking feature of the change in energy intensity over the last ten years is the decline in the OECD as a whole compared with increased intensity in developing countries.

Chart 1

After the First World War, demand for energy grew even faster and in the 1920s was increasing for the world as a whole by nearly 5 per cent every year. Then came the 1930s and, with the demand for energy actually declining in the depression years, growth over the whole decade averaged well below 2 per cent per annum.

The 1950s and 1960s saw the most rapid expansion in the use of commercial energy. In the two decades between 1950 and 1970, the amount of energy used almost trebled and annual average growth reached 5.4 per cent. At the same time, the economies of the industrialized countries were growing at around 5 per cent. It was no coincidence that this was also the era of cheap and increasingly available oil supplies and demand for oil averaged 8 per cent per annum over the same period. The 'economic miracles' in western Europe and elsewhere were in progress with help from cheap Middle East oil. There was a widely held perception that energy demand growth and economic growth were naturally and continually linked in a one-to-one relationship. The world seemed to have discovered the secret of perpetually high economic growth.

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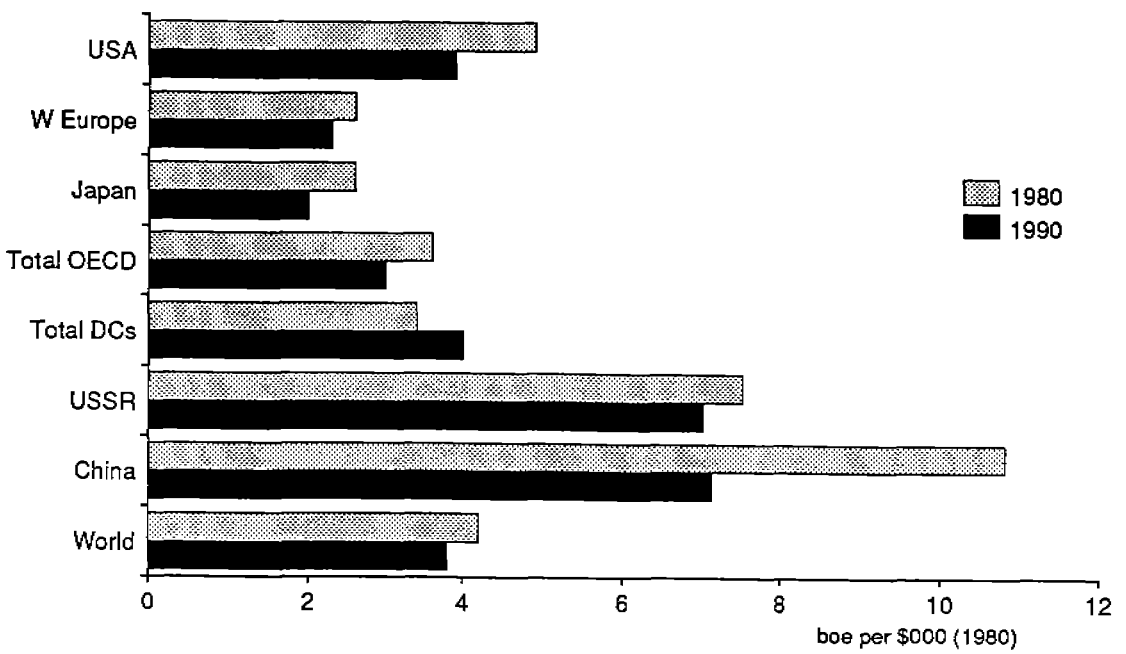

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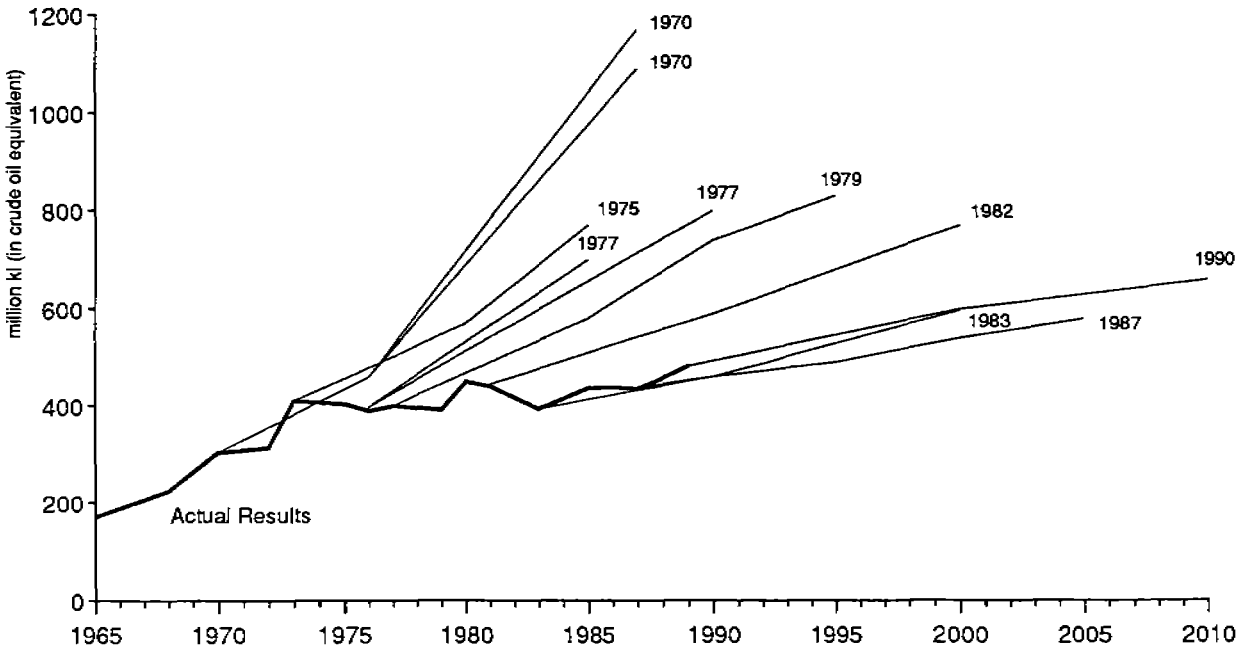

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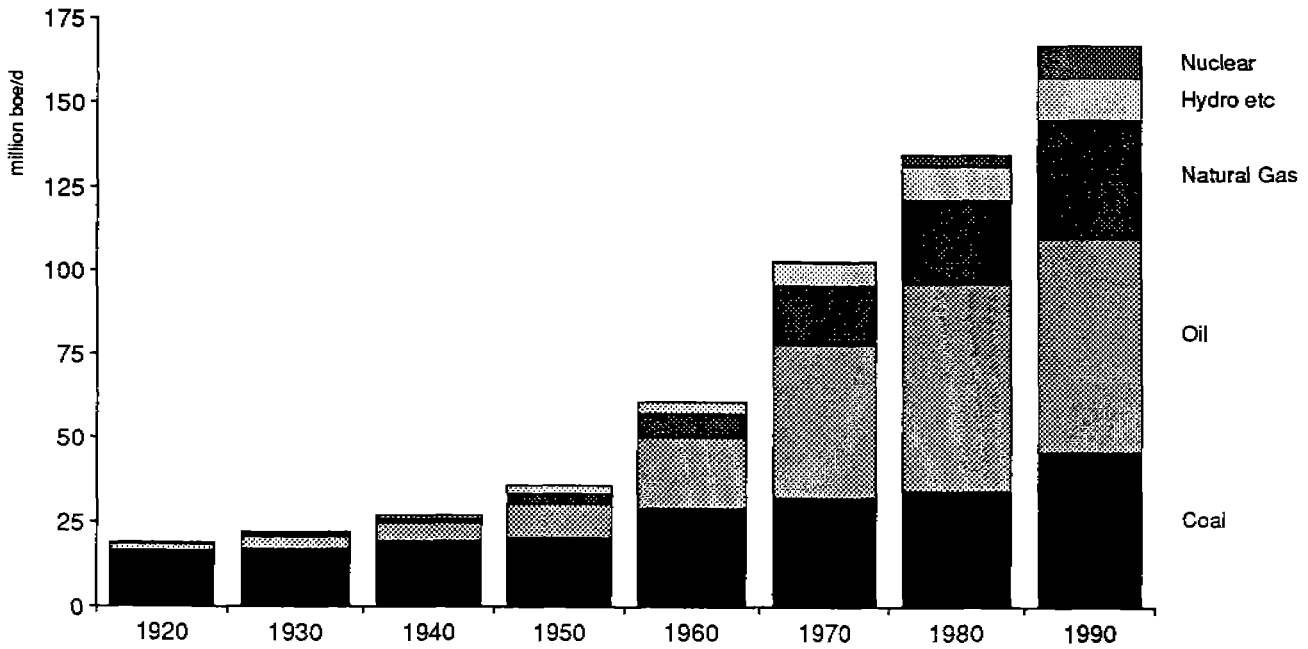

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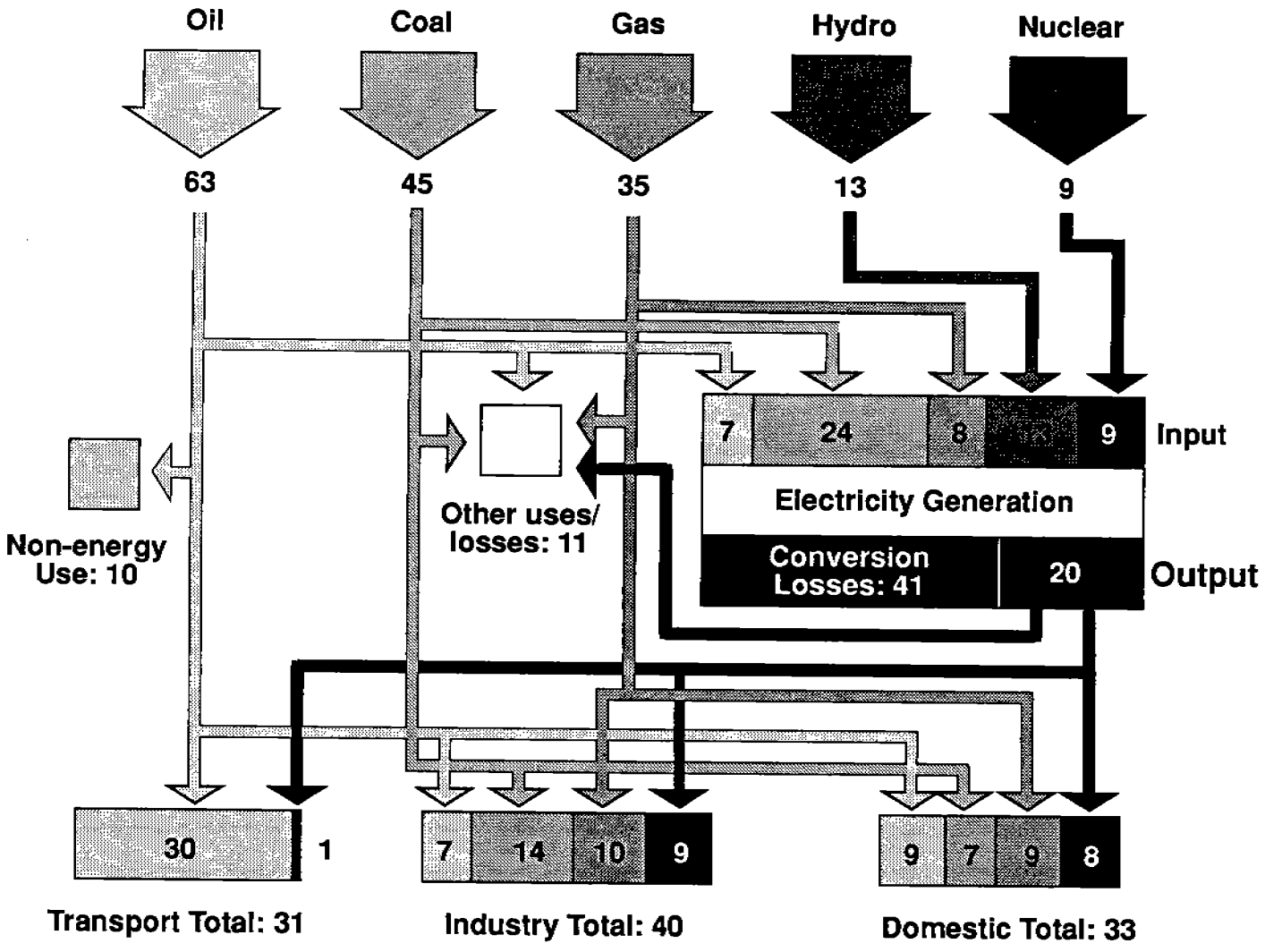

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