PART I: MEETING DEMAND AND FUELING GROWTH

1. World Energy Trends

Energy Consumption, Production, and Growth

5. Total world consumption of commercial or marketed energy[1] stood at 10.5 gigatons of oil equivalent (Gtoe) in 2003. As shown in **Figure 1**, fossil fuels[2] account for almost 80% of global primary energy supplies, with the remainder provided by nuclear, large hydro, traditional biomass, and new renewables. Fossil fuels make up 83% of the energy consumed in the Organisation for Economic Co-operation and Development (OECD) countries, compared with 72% in the Asia and Pacific region and only 34% in Sub-Saharan Africa. The production and shares of electricity supplies show similar variation between regions and in the energy mix used for generation (**Figure 2**). Traditional biomass constitutes, by far, the biggest single source of energy for large numbers of people in non-OECD countries, providing for a quarter of total energy consumption in developing Asia and as much as 70% in Sub-Saharan Africa (reaching over 80% in the case of some countries), but only 3% in industrialized countries and less than 10% on a worldwide basis (**Figure 3**).[3]

6. **Figure 4** shows the steady growth in global total primary energy supply[4] in recent years and forecasts for the future. However, this growth has historically also varied considerably between the developed and developing countries. Between 1990 and 2001, for instance, average annual energy use increased by 3.2% in developing countries, more than twice the 1.5% growth for industrialized countries, spurred by higher rates of population increase and economic activity in the former.

7. Global energy consumption is, however, highly skewed between geographical boundaries, with the OECD countries accounting for 44% of it with less than a fifth of the world's population. Energy consumption, therefore, varies widely from region to region (**Figure 5**), with a person in industrialized North America using, on average, almost eight times more energy than his counterpart in developing Asia (**Figure 6**). This is brought about by differences in both

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[1] Following common practice, in this paper the term "commercial" or "marketed" energy refers to fossil fuels (oil, coal, and natural gas), nuclear energy, and large-scale hydro and wind power. The term "traditional energy" is used to denote locally collected and often unprocessed biomass-based fuels, such as crop residues, wood, and animal dung, which are mostly used non-commercially (i.e., noncommercial energy). Although traditional energy sources can be used renewably, the term "new renewables" refers to modern biofuels, wind, solar, small-scale hydropower, marine, and geothermal energy.

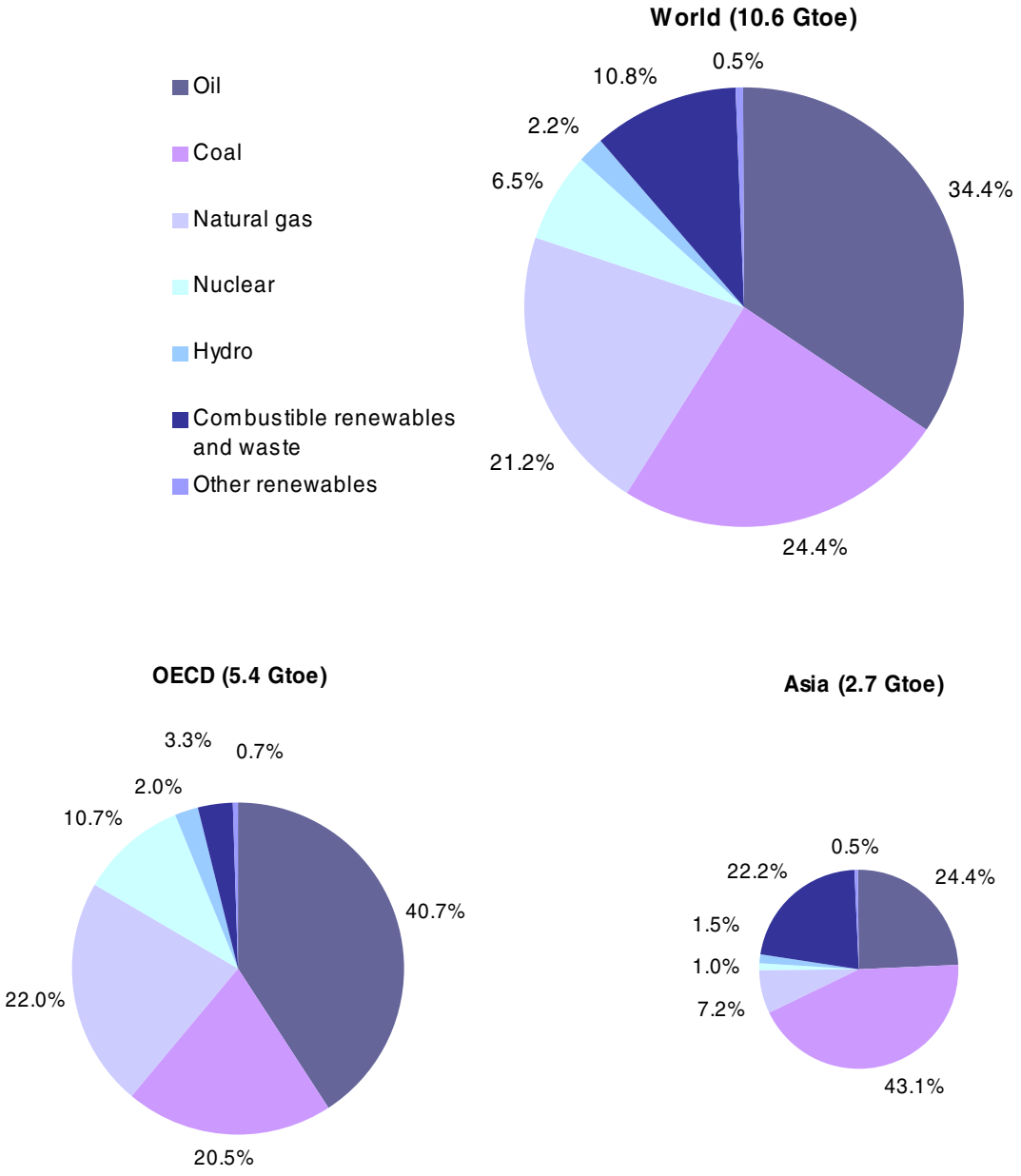
[2] Consisting of crude oil, petroleum products, natural gas, and coal.

[3] For consistency, in this paper "Asia" includes the People's Republic of China (PRC) but excludes the Middle East and OECD countries; "Developing Asia" includes the PRC, East Asia, and South Asia; "Middle East" includes Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, and Yemen; "Middle East and North Africa (MENA)" comprises the Middle East and Algeria, Egypt, Libya, Morocco, and Tunisia; "Africa" includes Algeria, Angola, Benin, Cameroon, Republic of Congo, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Libya, Morocco, Mozambique, Namibia, Nigeria, Senegal, South Africa, Sudan, United Republic of Tanzania, Togo, Tunisia, Zambia, Zimbabwe and Other Africa; "Latin America and Caribbean" excludes Mexico; "OECD Pacific" comprises Australia, Japan, the Republic of Korea, and New Zealand; "Former USSR" comprises Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Moldova, the Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan; "Non-OECD Europe" consists of Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Gibraltar, Macedonia, Malta, Romania, and Slovenia; "OECD North America" includes Mexico; and "OECD" includes all members of the Organisation for Economic Co-operation and Development as of 1 February 2006, i.e., Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, the Republic of Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom (UK), and the United States (US).

[4] Total primary energy supply (TPES) is the indigenous production of energy, plus imports and positive stock changes, minus exports and international marine bunkers.

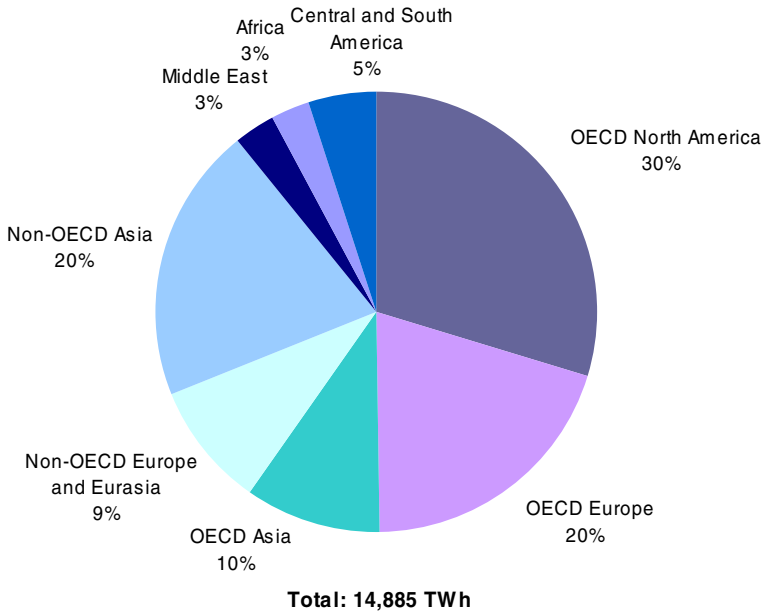
the availability as well as access to and patterns of use of energy supplies across—and within—disparate economic groupings, and is discussed in more detail for Asian countries later in **Section 2**.

Figure 1: Primary Energy Use by Source, 2003



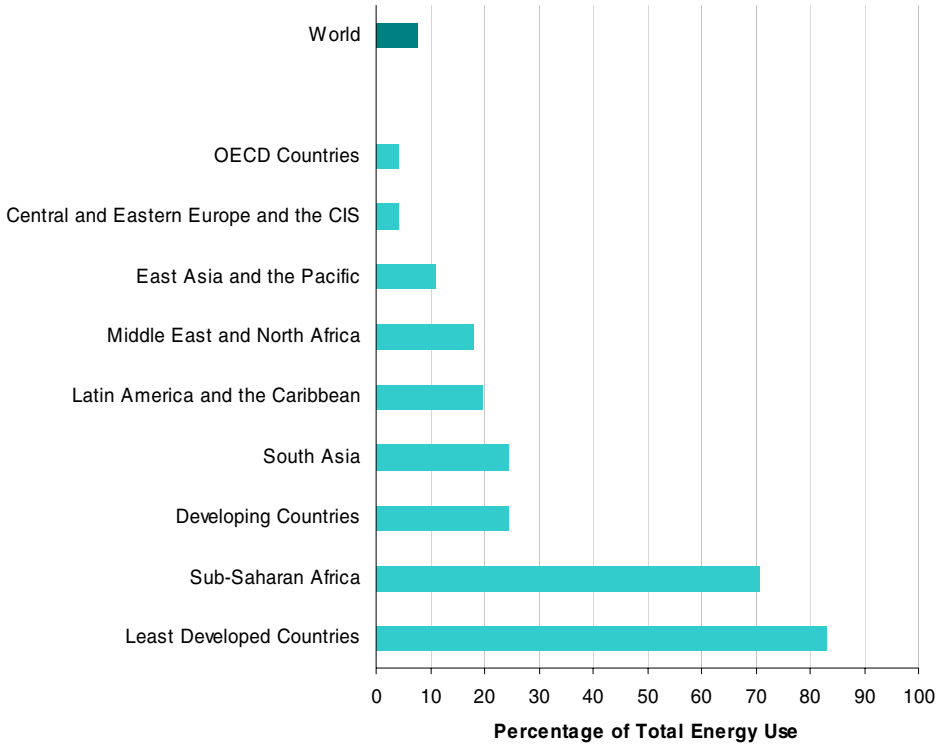
Gtoe = gigaton of oil equivalent; OECD = Organisation for Economic Co-operation and Development.
Source: International Energy Agency (IEA). 2003. *Energy Statistics and Energy Balances.* Paris: IEA. Available: www.iea.org/textbase/stats.

Figure 2: World Electricity Generation from Central Producers by Region, 2003



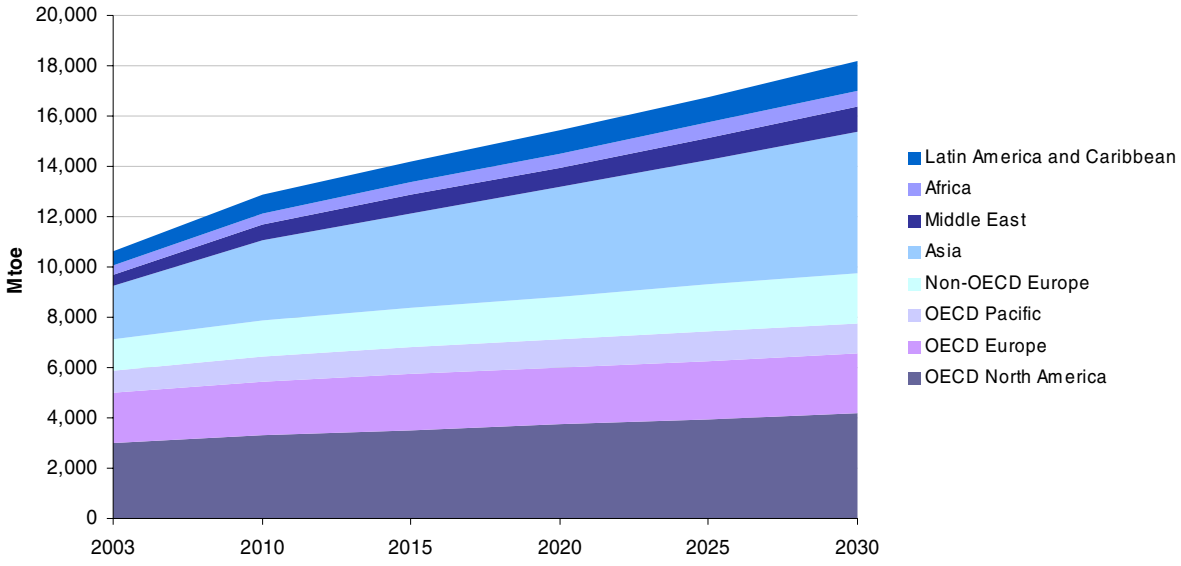
OECD = Organisation for Economic Co-operation and Development; TWh = terawatt-hour.
Source: US Department of Energy, and Energy Information Administration (DOE/EIA). 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

Figure 3: Traditional Fuel Use as Percentage of Total Energy Consumption by Region, 2002



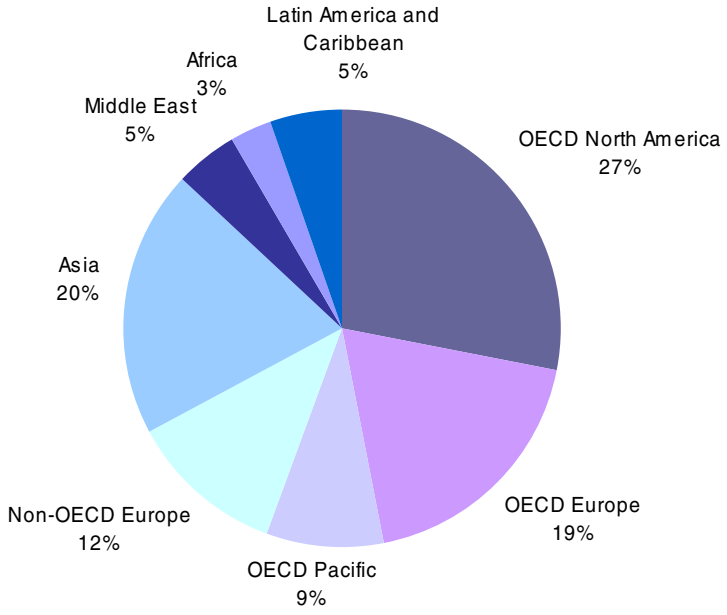
CIS = Commonwealth of Independent States; OECD = Organisation for Economic Co-operation and Development.
Source: United Nations Development Programme (UNDP). *Human Development Report 2005*. New York: UNDP.

Figure 4: World Primary Energy Consumption by Region, 1980–2030



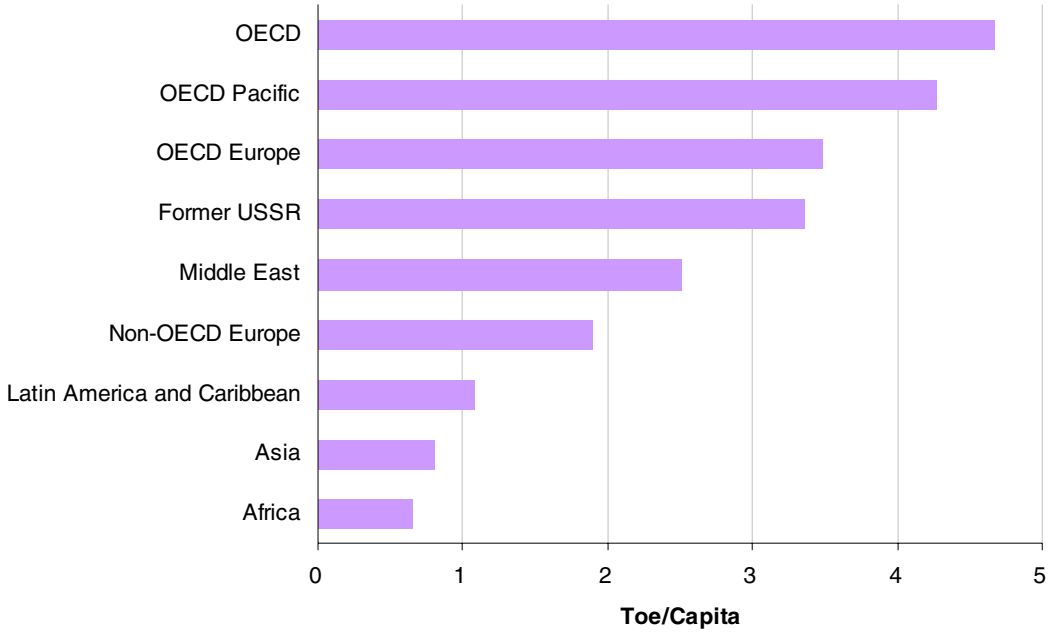
Mtoe = million tons of oil equivalent; OECD = Organisation for Economic Co-operation and Development.
Source: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

Figure 5: World Energy Consumption by Region, 2003



Gtoe = gigatons of oil equivalent; OECD = Organisation for Economic Co-operation and Development.
Source: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

Figure 6: Per Capita Energy Use (Commercial and Non-commercial) by Region, 2003



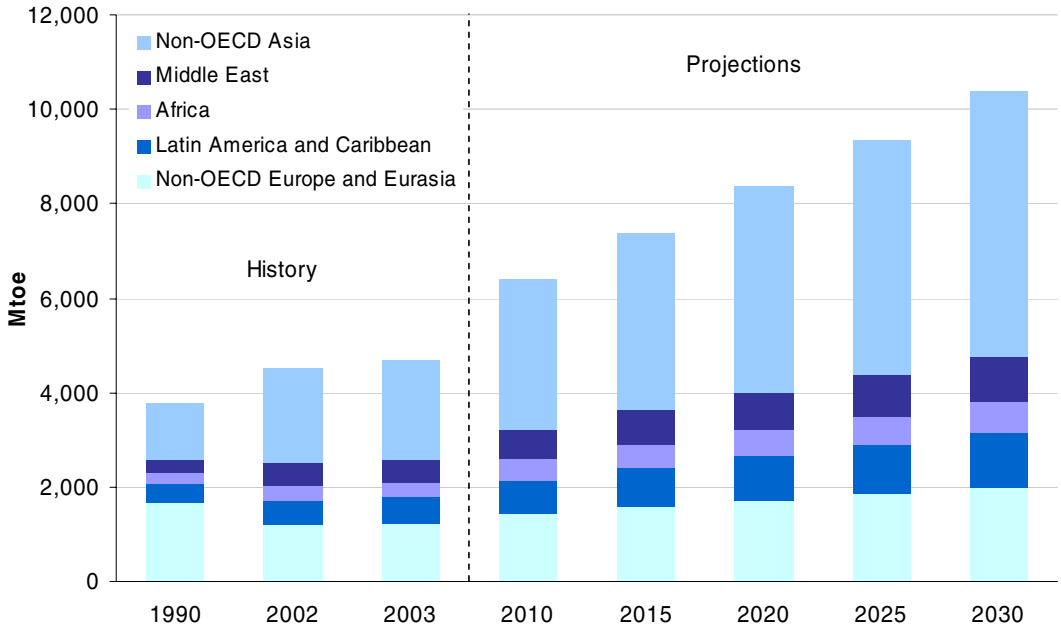
OECD = Organisation for Economic Co-operation and Development; Toe = ton of oil equivalent; USSR = Union of Soviet Socialist Republics.
Source: UNDP and World Energy Council (WEC). 2004. *World Energy Assessment: Overview 2004 Update.* New York: UNDP and WEC.

Energy Demand Projections

8. Global energy forecasts differ in terms of absolute figures, but agree on the prospects for strong, steady growth over at least the next two-and-a-half decades, despite the dramatically rising oil prices witnessed in recent years. For example, the International Energy Agency (IEA) estimates world energy consumption to increase by 52% to 16.3 Gtoe in 2030 in the baseline, or "reference", scenario over 2003 levels (based on average annual world gross domestic product (GDP) growth of 3.2% over the projection period), while the Energy Information Administration (EIA) of the Government of the United States (US) projects total demand touching 18 Gtoe, or a 71% increase, at the end of the same period (based on world GDP growth rate of 3.8%). Major oil companies, such as Exxon Mobil, forecast an intermediate figure of 16.7 Gtoe for world energy demand by 2030 (with GDP growth averaging 2.8% per year). These projections translate into an annualized average growth rate in global energy demand over the corresponding period of about 1.6%–2.0%. For most of the remainder of this paper, unless otherwise stated, the discussion is predominantly based on the latest IEA and EIA forecasts and analyses.

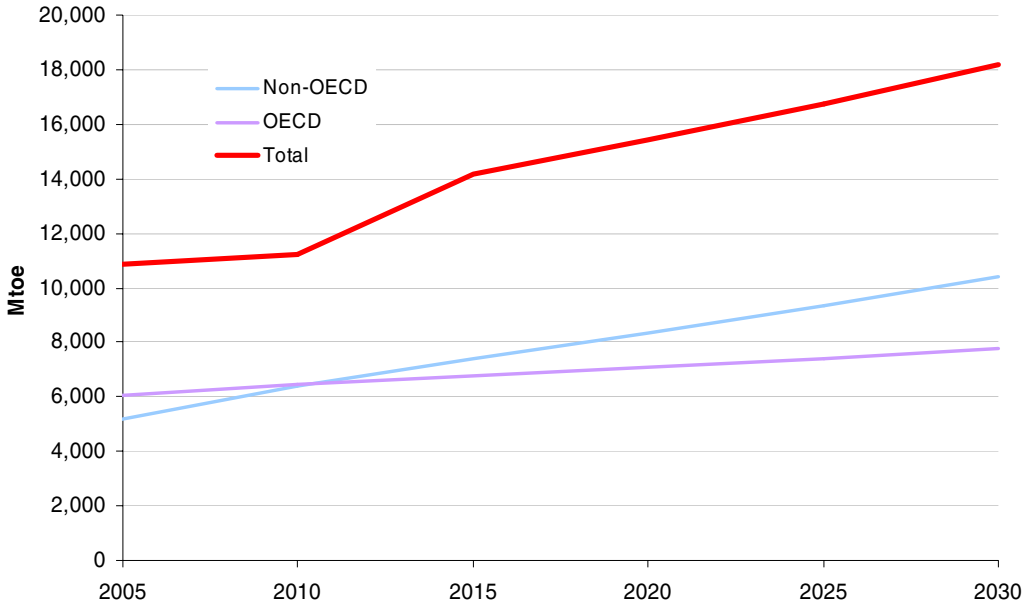
9. The IEA predicts that more than two-thirds of world energy growth will stem from developing country needs, mostly from those belonging to non-OECD Asia. **Figure 7** shows that demand in these countries nearly triples over the projection period 2003–2030. As per historical trends, energy demand growth in non-OECD countries at 3% per year will be three times that in OECD countries during this interval, and total non-OECD energy consumption is expected to begin outstripping OECD demand as early as 2011 (**Figure 8**).

Figure 7: Energy Use in Non-OECD Regions, 1980–2030



Mtoe = million tons of oil equivalent; OECD = Organisation for Economic Co-operation and Development.
Source: International Energy Agency. Available: www.iea.org.

Figure 8: World Primary Energy Use, 2005–2030



Mtoe = million tons of oil equivalent; OECD = Organisation for Economic Co-operation and Development.
Source: International Energy Agency. Available: www.iea.org.

10. In line with current supply patterns, fossil fuels will continue to dominate primary energy supplies, and are actually expected to increase slightly to 81% of the total by 2030. Oil

consumption will reach 115 to 121 million barrels per day (mbpd) in 2030, up from 79 mbpd in 2003, with the transport sector (road, rail, sea, and air) expected to account for one half to two thirds of the increase, given that alternative transportation energy sources, such as biofuels and fuel cells, will not substantially displace petroleum-based products over this timeframe on account of economic and associated infrastructure imperatives. Oil demand for industrial, commercial, and residential uses (cooking and heating) will also increase, particularly in developing countries, while its share in power generation and other non-transport uses will decline.

11. Natural gas consumption will grow rapidly, almost doubling from 95 trillion cubic feet (tcf) in 2003 to 182 tcf by 2030, at an average rate of 2.4% per year, and could displace coal as the largest fossil fuel used within the next decade (according to IEA estimates). OECD countries will account for the majority of the increased gas used, although developing countries will witness the highest rates of increase in gas demand. In both cases, industrial use and power generation will be the primary drivers of the growth, given the advantages of natural gas over coal and oil in terms of power plant emissions, capital costs, and operational flexibility. By 2030, power generation will account for nearly half of the global consumption of natural gas.

12. Almost all regions of the world, except Japan, are expected to show an increase in coal use—equivalent to as much as 5.1 billion short tons, primarily for power generation—or a 2.5% average annual growth rate up to 2030. The largest increases in coal use will be in the PRC and India, which will together account for up to 70% of the global increase in coal demand. Coal will become increasingly competitive as natural gas and oil prices increase, and its projected share in total energy supply is predicted to range, as a result of this sensitivity, from 22% to 27%, compared with 24% in 2003.

13. Over the same projection period, non-OECD countries will see an average 3.9% annual growth in their electricity consumption (compared with only 1.5% for OECD nations), and worldwide electricity use will consequently more than double from 14.8 terawatt-hours (TWh) in 2003 to 30.1 TWh in 2030, requiring 4,800 gigawatts (GW) of new capacity addition. However, according to the IEA, although electrification rates will rise over this period, the number of people without electricity will decline only slightly from the present 1.6 billion to 1.4 billion on account of general population growth, with most of these living in Asia and Africa. The disparity between urban and rural access to electricity will remain, although the latter is expected to improve toward the second half of the period. Power generation will increasingly shift to cleaner fuels, spurred by rising oil prices, with natural gas and renewables increasing their shares at the cost of other fuels and collectively accounting for 44% of generation by 2030, up from 37% in 2003. However, coal-based power generation will continue to dominate worldwide electricity supply, especially in large power markets such as the US, the PRC, and India where available local resources and prices would favor coal over natural gas.

14. Nuclear power is expected to post 3.5% annual growth in non-OECD countries between 2003 and 2030, but its overall share in electricity generation will decline due to retirement of existing reactors, primarily in OECD countries, over the same period. Most notable increases in nuclear generation capacity (up to 70% of the total) are anticipated in non-OECD Asia, led by the PRC and India, which, along with the Republic of Korea, Japan, and the Russian Federation, will take the worldwide total from 361 GW in 2003 to 438 GW in 2030.

15. Grid-connected hydroelectricity and other renewable energy is projected to increase by 2.4% per year over the 2003–2030 period, specially as these become more cost-competitive due to both technology advances as well as rising fossil fuel prices, with the overall share of renewables in global energy rising marginally to around 10%. Large hydroelectric projects, especially in developing Asia, will provide most of this increase, although their overall share in

electricity generation is expected to remain flat or to decrease, while that of other renewables, notably wind and biomass, increases three-fold to 6% by the end of this period. The largest increase in non-hydro renewables will be witnessed in OECD Europe, given the strong policy support provided to renewable forms of power generation there. Overall, the share of renewables in global energy supplies is expected to remain constant at 11% over the projection period.

16. Traditional biomass is projected to continue to be used for cooking and heating by large numbers of people in developing countries. Those relying exclusively on the unsustainable use of such resources are actually projected to increase from the present 2.4 billion to more than 2.6 billion by 2030. The low efficiency and high economic costs of traditional fuels compared with the benefits of modern energy supplies will therefore remain a significant issue for most of the developing world, especially among the poor who are its main users, and would require more concerted efforts to address.

17. These energy demand projections are predicated on continued worldwide economic growth as well as assumed fossil fuel price forecasts. The former, in turn, depend on nations' demographic and human resource development trends, labor participation, productivity, political and regulatory climate, savings, and capital accumulation rates, among other factors, while the latter are influenced not only by current proved and recoverable reserves, but also by the cost and willingness of producers to invest in expanded production to meet increasing demand. In addition, as mentioned earlier, there exist large differences between geographical and economic groupings in terms of patterns and improvement in energy access, consumption, and intensity of use.

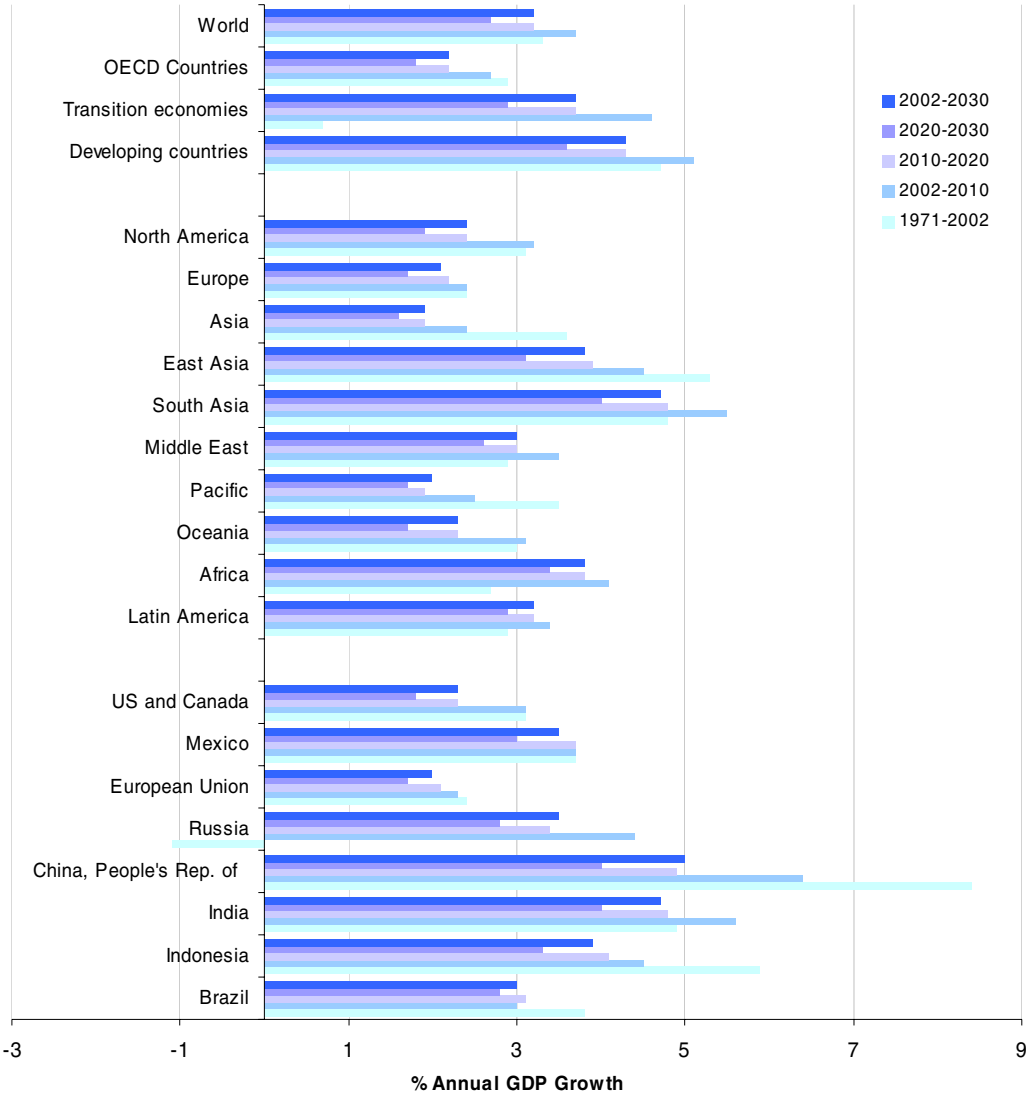
Economic and Consumer Growth

18. There are two growth factors that mainly determine future energy demand on a global or regional scale: economic activity and population. Economic activity is a primary determinant of energy demand, and energy projections are thus strongly influenced by assumptions about economic growth trends. The linear relationship between the two, based on historical data since 1971, has been found to be approximately 0.6% increase in primary energy consumption for each percentage increase in world GDP.[5] As mentioned earlier, the various energy projections quoted in this paper have been derived on different global economic growth assumptions, ranging from 2.8% to 3.8% average GDP growth per year. The higher projections are based on accelerated GDP growth compared with the 3.3% average witnessed over the past 30 years on account of increasingly liberalized macroeconomic policies, currency regulations, trade, and investment regimes being adopted by many countries which directly stimulate and facilitate economic transactions and growth. The assumed average world economic growth rate, in turn, masks important variation over different periods as well as between economic regions on account of the structures and development status of different national economies, as illustrated by the example shown in **Figure 9**. As expected, growth projections are higher for developing countries than for the OECD nations, and in almost every instance GDP growth is expected to gradually slow down over the coming 2 decades as economies mature. As they do so, many of these countries are also expected to make the transition from heavy industry to lighter manufacturing and services, which are less energy intensive. It is also noteworthy that economic growth assumptions can drastically affect such predictions, with the difference between the EIA's "high" and "low" GDP growth scenarios (of 4.6% and 3.1% average annual

[5] The income elasticity of energy demand, i.e., the increase in demand relative to GDP, has actually decreased from a worldwide average of 0.7 in the 1970s to about 0.4 in the 1990s, primarily on account of climatic cycles (e.g., warmer winters) and increased efficiency of use, although energy consumption for electricity production and transportation remain much more closely tied to GDP levels [IEA and OECD. 2004. *World Energy Outlook 2004*, p. 42].

growth, respectively) amounting to as much as 5,125 Mtoe in 2030, or an uncertainty of almost 30% with respect to the reference case demand projection for that year.

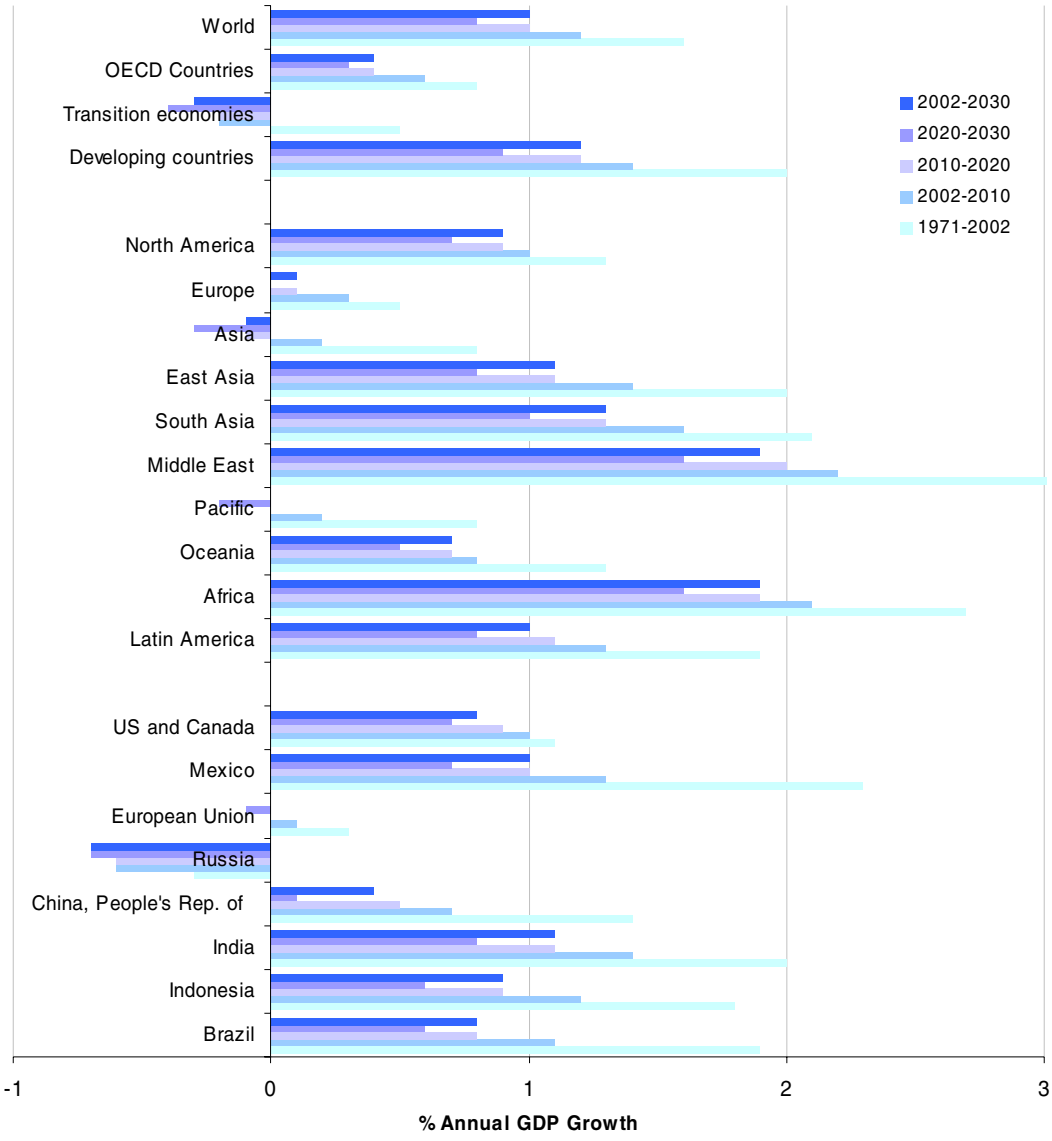
Figure 9: Economic Growth by Region, 1971–2030



GDP = gross domestic product; OECD = Organisation for Economic Co-operation and Development; US = United States.
Source: IEA and Organisation for Economic Co-operation and Development (OECD). 2004. *World Energy Outlook 2004.* Paris: IEA.

19. Sustaining the growth in energy demand and fueling economic activity is a projected worldwide increase in population of 1% per annum, taking the total from 6.2 billion in 2002 to 8.1 billion in 2030. Again, in line with recent trends, population growth is expected to decline monotonically over the projection period, from 1.2% in the decade up to 2010 to 0.8% in the 10 years ending in 2030, even though regional disparities in growth rates (as well as population densities) will remain significant (**Figure 10**).

Figure 10: Population Growth by Region, 1971–2030



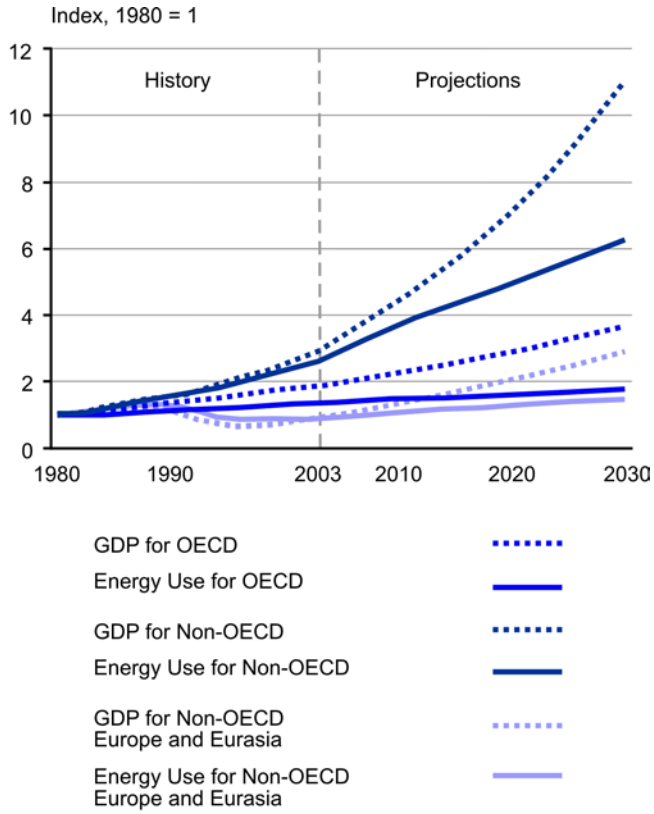
OECD = Organisation for Economic Co-operation and Development; US = United States.
Source: United Nations Population Division (UNPD). 2003. *World Population Prospects: The 2002 Revision.* New York: UNPD.

Energy Use and Intensity

20. The relationship between energy use and GDP, or "energy intensity", is important in determining the actual energy demand in an economy at any given time. Demand projections are complicated by the fact that this factor can also vary across national boundaries and over time as economies and local conditions evolve. This is especially true for developing economies, where the correlation between energy consumption and GDP is strong; in OECD countries the relationship is not as evident, with energy demand lagging behind economic growth (**Figure 11**). Indeed, emerging economies are now beginning to exhibit similar trends, lending credence to the conclusion that as nations develop, their economic growth begins to decouple from energy use and energy intensity declines, a sign of increasingly efficient resource

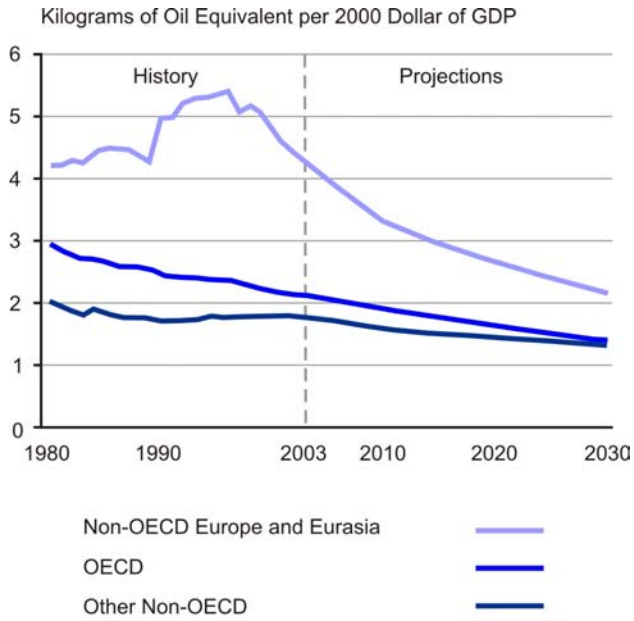
use. The historical experience in the case of non-OECD Europe has been less compelling until very recently (with the stabilization of the Russian and Ukrainian economies), but this is attributed to the ramifications of the collapse of the former Soviet Union. In the future, however, energy intensity is expected to continue to decline in both developed and developing countries, with the respective curves converging in the distant future (**Figure 12**). The rate at which energy intensity declines is influenced by the rate of economic growth: the faster the growth, the steeper the fall in energy intensity. At a very basic level, this is symptomatic of expenditure on new energy-consuming stock (vehicles, machinery, appliances, etc.) in developing economies as individuals' disposable incomes rise and such items become affordable by a greater number of people, while in developed countries the bulk of the population already owns such stock, so that spending is for replacement purposes only, invariably with more efficient equipment, which weakens the link between income level and energy used. The EIA estimates worldwide energy intensity to improve at an annual rate between 1.5% and 1.9%, depending on different economic growth scenarios.

Figure 11: Growth in Energy Use and GDP by Region, 1980–2030



GDP = gross domestic product; OECD = Organisation for Economic Co-operation and Development.
Source: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

Figure 12: Energy Intensity by Region, 1980–2030



OECD = Organisation for Economic Co-operation and Development.
Source: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

21. In terms of end use, energy consumption can be broadly divided between residential (i.e., non-transportation household use), commercial (i.e., services and institutional use), industrial (i.e., manufacturing, agriculture, mining, and construction use), and transportation (road, rail, sea, and air). The largest of these are the last two, in that order (**Figure 13**), together accounting for over three quarters of all energy consumed, a share that is expected to increase further in the future as they also exhibit the fastest average annual growth rates (3.2% and 2.3%, respectively), especially for developing countries (**Figure 14**). Residential energy use is also expected to register high growth in the developing world (2.7% per year) as greater numbers of households are electrified and gain access to other modern fuels. The difference in industrial energy growth rates over the projection period between OECD and non-OECD countries (1.2% versus 3.2%) is explained by the shift of energy-intensive industry (e.g., heavy manufacturing) away from North America and Europe to Asia. Energy for transportation will continue to rely primarily on petroleum in the absence of a viable and widely available alternative, even as the market for hybrid vehicles, ethanol-blended gasoline, and biodiesel expands. Transportation energy growth will be fueled by a robust expansion in aviation as well as in the numbers of vehicles in developing countries, led by the large growing economies and populations of the PRC and India, and dampened only by the ability of these countries to provide matching investments in related physical infrastructure (roads, airports, etc.).

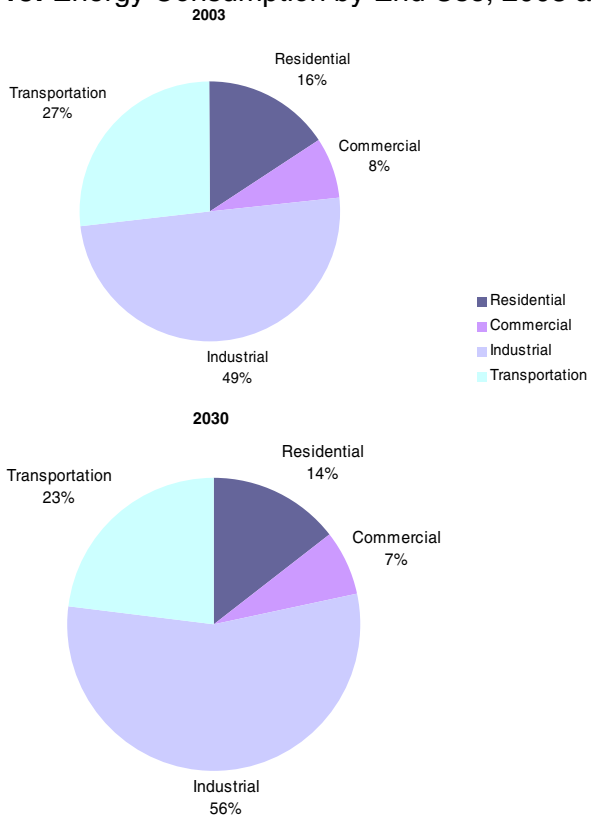
22. Another important aspect of global comparisons in energy use is the availability of and access (both physical and financial) to modern energy supplies between (as well as within) populations of different countries, a topic that will be analyzed in greater detail later in this paper (see **Part II**).

Resource Availability and Pricing

23. By 2030, fossil fuels are expected to contribute almost 82% of primary energy supplies, up from just under 80% in 2002 (**Figure 15**), with most of the increase coming from natural gas (from 21.2% to 25.1%) and oil maintaining its share at 35%. Nuclear and biomass conversions will decline in the overall primary fuel mix, while the share of renewables other than hydro and biomass is expected to triple over the period. Overall, growth in global energy demand in the reference scenario is expected to maintain the previous 3 decades' average of 2% per annum until 2030, although some estimates predict a slight decline on account of improving energy intensity, with coal and natural gas use accelerating (**Figure 16**).

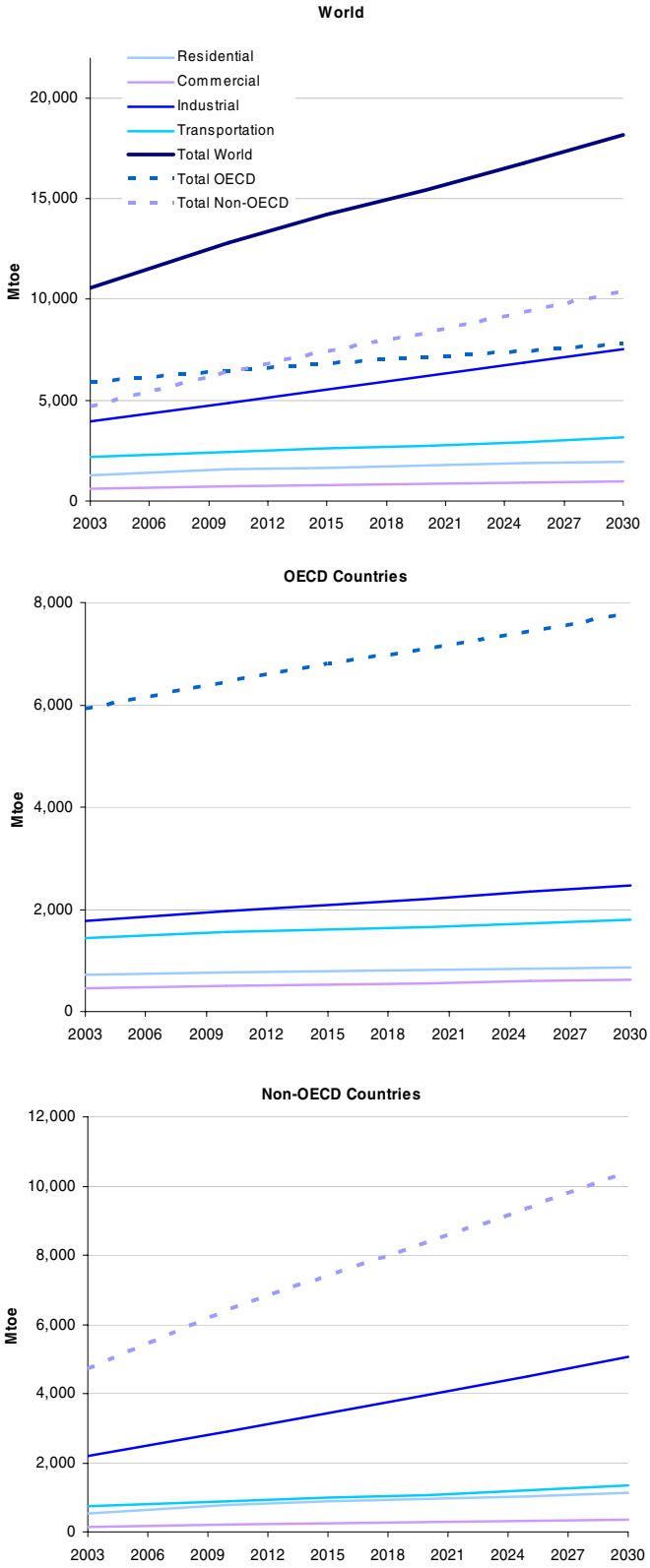
24. **Figure 17** compares the increase in primary energy demand by fuel type over past and future decades. It is evident that fossil fuel use, led by oil and natural gas, will continue to satisfy the bulk of the increased demand, with renewable energy use also accelerating but remaining low in absolute terms, while hydro capacity growth will remain flat. Worldwide fossil fuel resources are, however, adequate to cater to this increased demand, with currently known oil and gas reserves exceeding cumulative projected consumption to 2030 even without new finds, although substantial additional investments will be required to expand production and avoid premature "peaking". Known oil reserves are not expected to reach their peak production levels over the next quarter century, and gas reserves are deemed sufficient to last for 66 years at present production rates. Current recoverable coal reserves, at over 1,000 billion tons, are also estimated to be adequate for 70 years even at the higher projected rates of consumption. Resource availability is also not an issue with nuclear and solar energy, although hydro and onshore wind power is expected to face dwindling options in some regions within this period. Waste-to-energy conversion will also be limited by raw fuel availability constraints.

Figure 13: Energy Consumption by End Use, 2003 and 2030



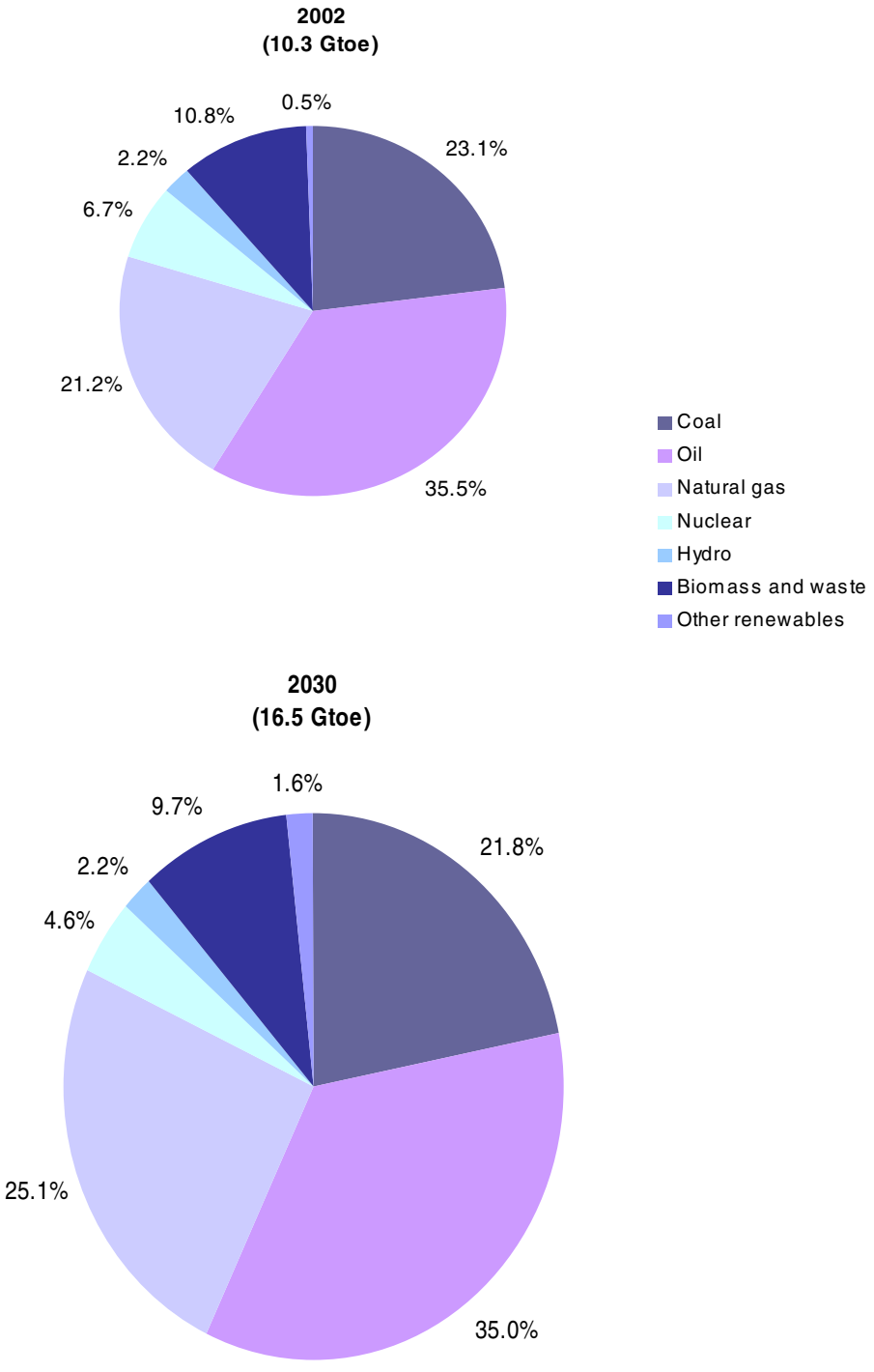
Source: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

Figure 14: Growth in Energy Use, 2003–2030



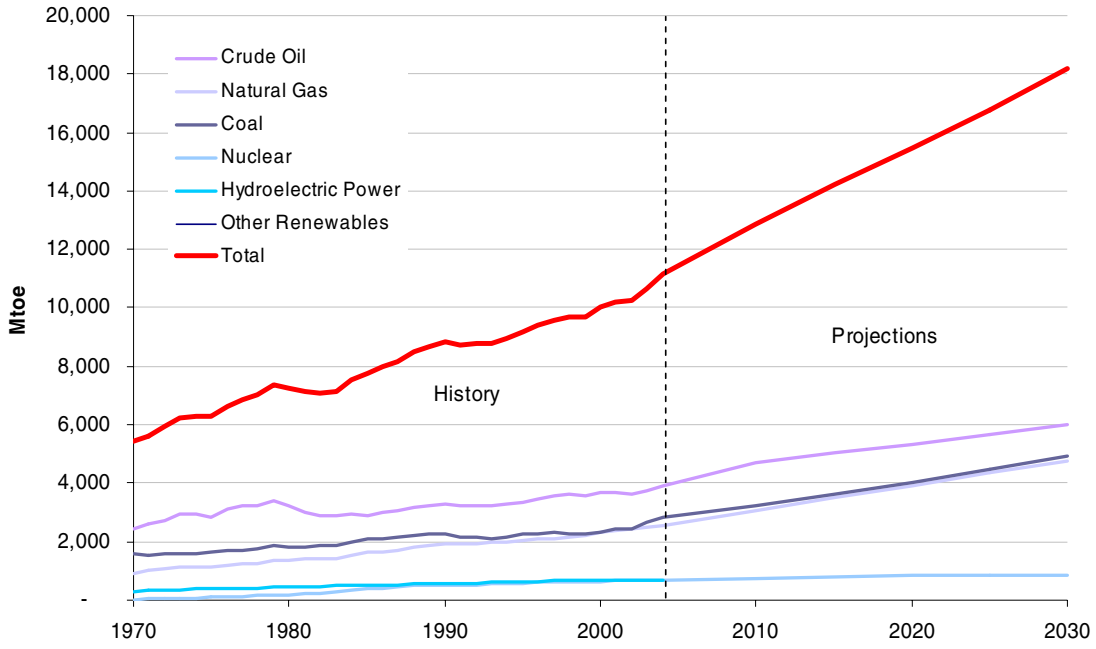
Mtoe = million tons of oil equivalent; OECD = Organisation for Economic Co-operation and Development.
Source: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

Figure 15: World Primary Energy Consumption by Fuel, 2002 and 2030



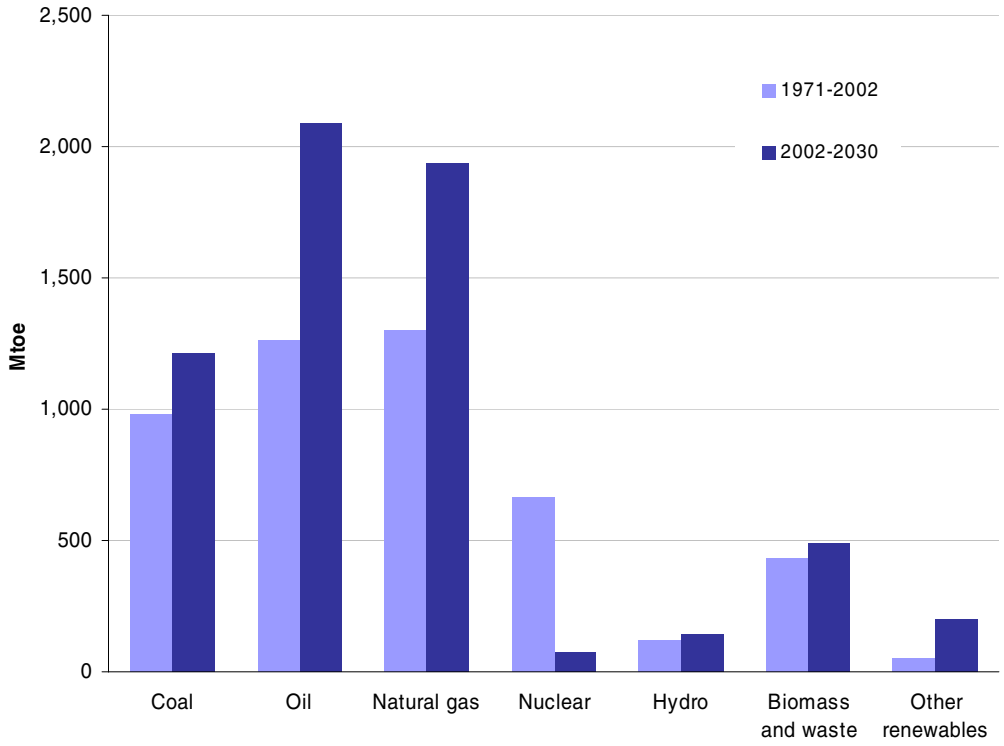
Gtoe = gigatons of oil equivalent.
Source: IEA and OECD. 2004. *World Energy Outlook 2004.* Paris: IEA.

Figure 16: World Primary Energy Production by Fuel, 1970–2030



Mtoe = million tons of oil equivalent.
Source: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

Figure 17: Change in World Energy Demand by Fuel, 1971–2030

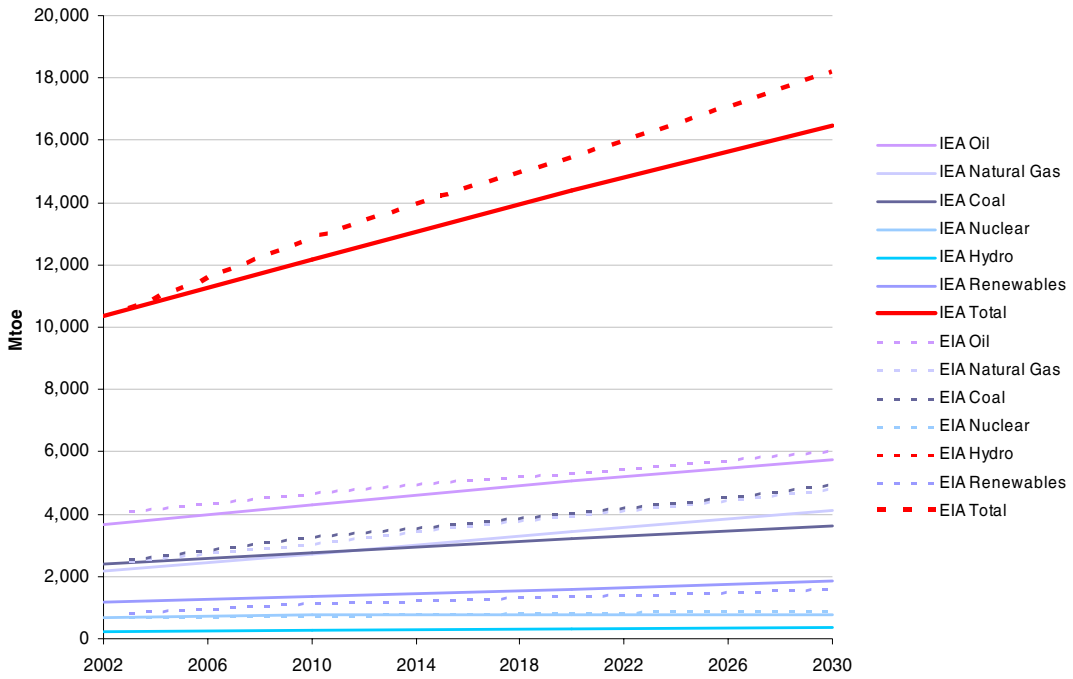


Mtoe = million tons of oil equivalent.
Source: IEA and OECD. 2004. *World Energy Outlook 2004.* Paris: IEA.

25. As the world's electricity consumption doubles to almost 32,000 TWh in 2030, some 4,800 GW of new generation capacity would be required. Coal is expected to continue to be the single largest fuel source for power production, while more than half of world natural gas consumption will also be for this purpose. The share of non-hydro renewables and gas in power generation will increase, while that of nuclear will decline, although increasing in terms of installed capacity.

26. Given their persisting dominance in global primary energy supplies, fossil fuel prices will continue to set the competitive benchmark for almost all other energy resources. The historical volatility and recent dramatic increases in oil prices in particular are the biggest single uncertainty in determining growth drivers for other energy sources. For instance, based on relative cost trends, the IEA predicts natural gas to overtake coal use within the next decade, while the EIA forecasts coal to become even more competitive, given rising oil and gas prices, and its share to continue to exceed that of natural gas to 2030 and beyond. Thus, comparative price uncertainties add another layer of complexity in fuel supply projections on top of those deriving from economic growth assumptions. A measure of the magnitude that such uncertainties can attribute to global fuel consumption estimates can be assessed from the differences in the demand trends forecast by the IEA and EIA in their respective reference scenarios, as illustrated in **Figure 18**. Primarily due to differences in coal and gas use predictions, the IEA projects a lower overall annual energy demand increase of 1.7% compared with the EIA's continuation of past decades' growth rate of 2% per year.

Figure 18: World Primary Energy Demand Projections by Fuel, 2002–2030

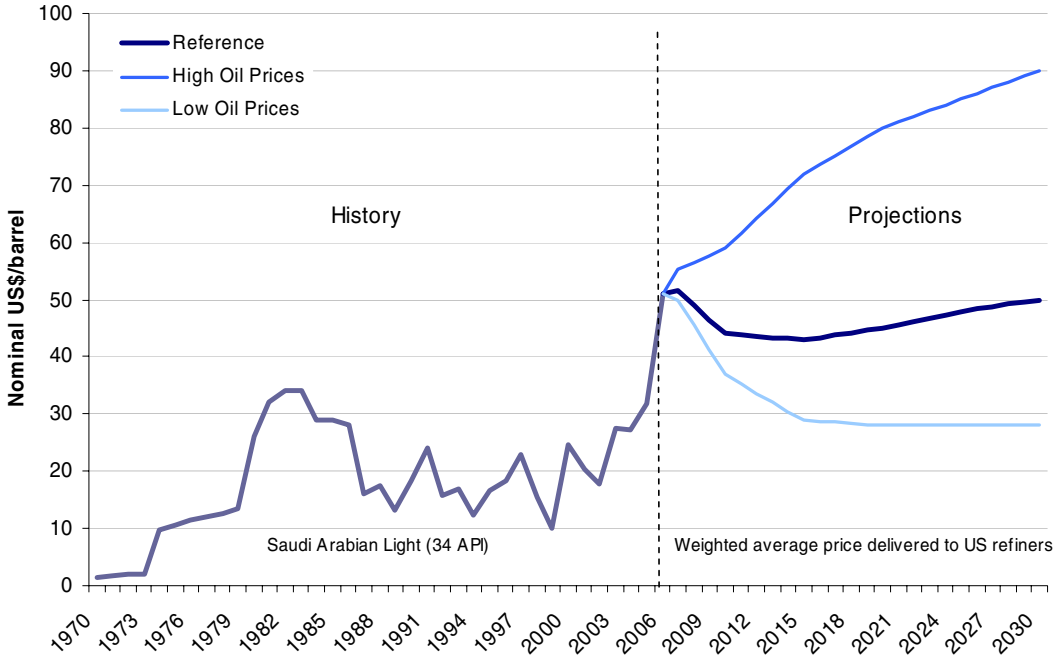


EIA = Energy Information Administration; IEA = International Energy Agency; Mtoe = million tons of oil equivalent.
Sources: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE; IEA/OECD. 2004. *World Energy Outlook 2004.* Paris: IEA.

27. Projected oil price forecasts are affected less by inaccuracies in worldwide reserve estimates than by the extent to which producing countries would be willing to invest in expanding production facilities to keep up with demand within the given timeline. The combined effect of these factors on future oil prices is illustrated in **Figure 19**, which shows a variation of over 220% between the "high" and "low" price projections for 2030. In addition to long-term trends, prices are also subject to short-lived fluctuations caused by various other externalities, such as political exigencies, as evident in the fluctuating historical data graphed in the same diagram. Gas prices have tended to track oil price increases in recent months, but are expected to increase somewhat more gradually in the future.

28. Given its dominant share in the world's primary energy resources because of its versatility as a fuel, and in the world's commodity markets because of its fungible nature, prices of oil will continue to have a major impact on global energy trade patterns—as well as the prospects for competing fuels or alternative energy production and end-use technologies. High levels of future oil price uncertainties therefore make it difficult to assess and develop an alternative global energy scenario based on comparative economics alone.

Figure 19: Crude Oil Prices, 1970–2030



Source: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

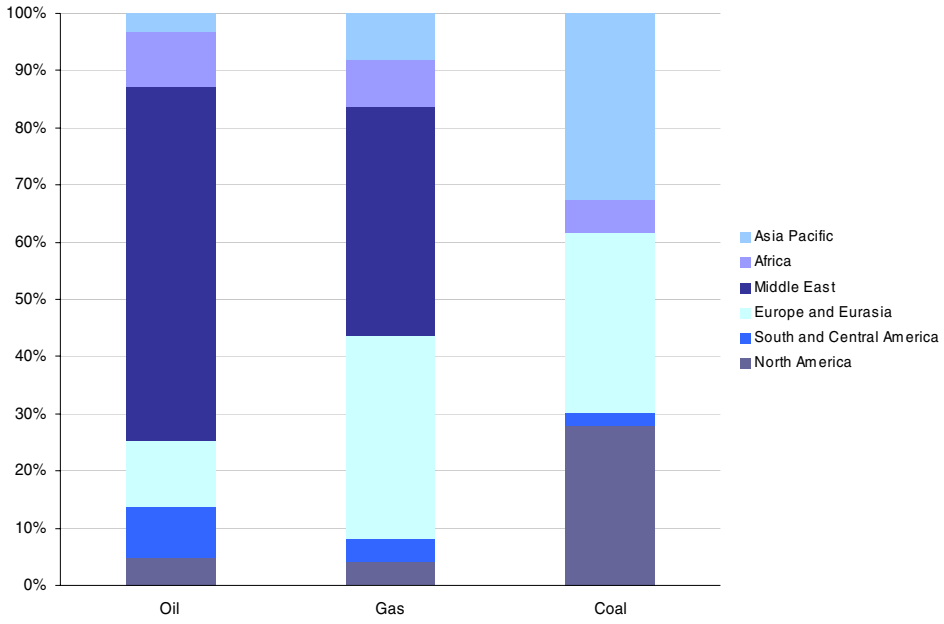
Energy Transfers, Investments, and Technologies

Energy Trade

29. The world's fossil fuel reserves are highly concentrated geographically (**Figure 20**), with major consumers having to meet large proportions of their needs, especially for oil and natural gas, through imports (**Figure 21**). Coal use is largely indigenous to major consumers (e.g., the US, the PRC, India), although growing worldwide demand is increasing trade in this fuel as well.

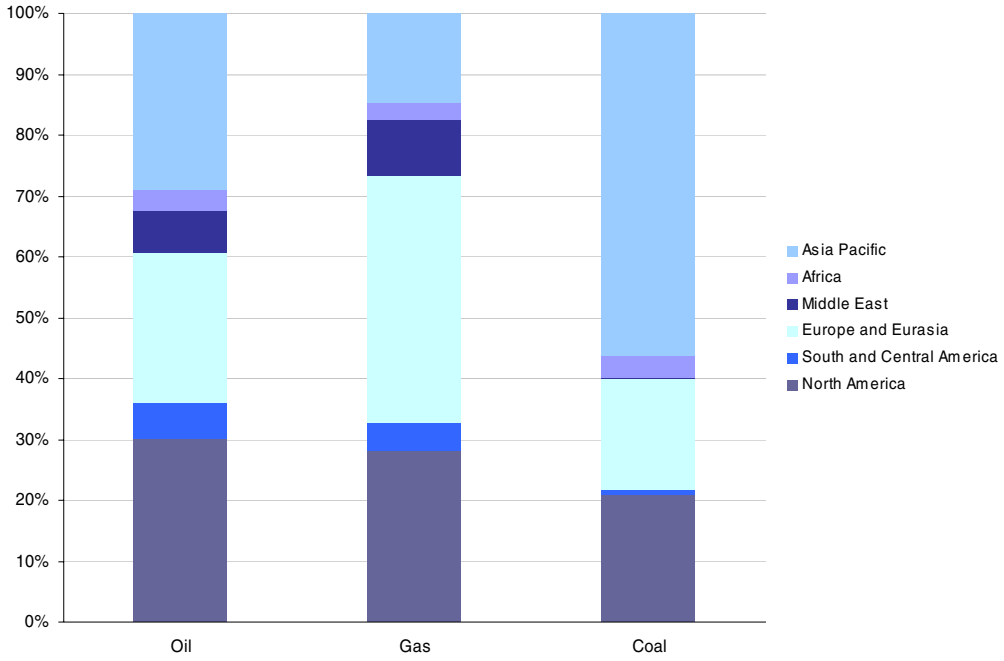
30. According to both EIA and IEA forecasts, worldwide oil trade is expected to rise significantly over the coming decades and double over current levels by the year 2030, with all major importing regions sharply increasing their dependence on imported petroleum (**Figure 22**). Flows to developing Asia will increase the most, accounting for 85% of the rise, of which 62% would be destined for the PRC alone. By 2030, the OECD countries will be dependent on imported oil for 85% (with the European Union and OECD Pacific at about 95%) and developing Asia for 78% of their needs. The bulk of this trade is going to continue to emanate from the Middle East (increasing from 17 mbpd in 2003 to 46 mbpd, or two thirds of the world total, in 2030), with exports from Africa, Latin America, and the Russian Federation initially increasing before stabilizing or declining by 2020. Such increased trade, amounting to more than half of all production and relying on a relatively small number of supplier regions and shipping routes—many vulnerable to sudden political disruption—would have important implications in terms of energy security for the importing countries and, by extension, for the world's economy. Because of this, oil price volatility can only be expected to increase in reaction to real or perceived market shocks.

Figure 20: Fossil Fuel Reserves by Region, 2005



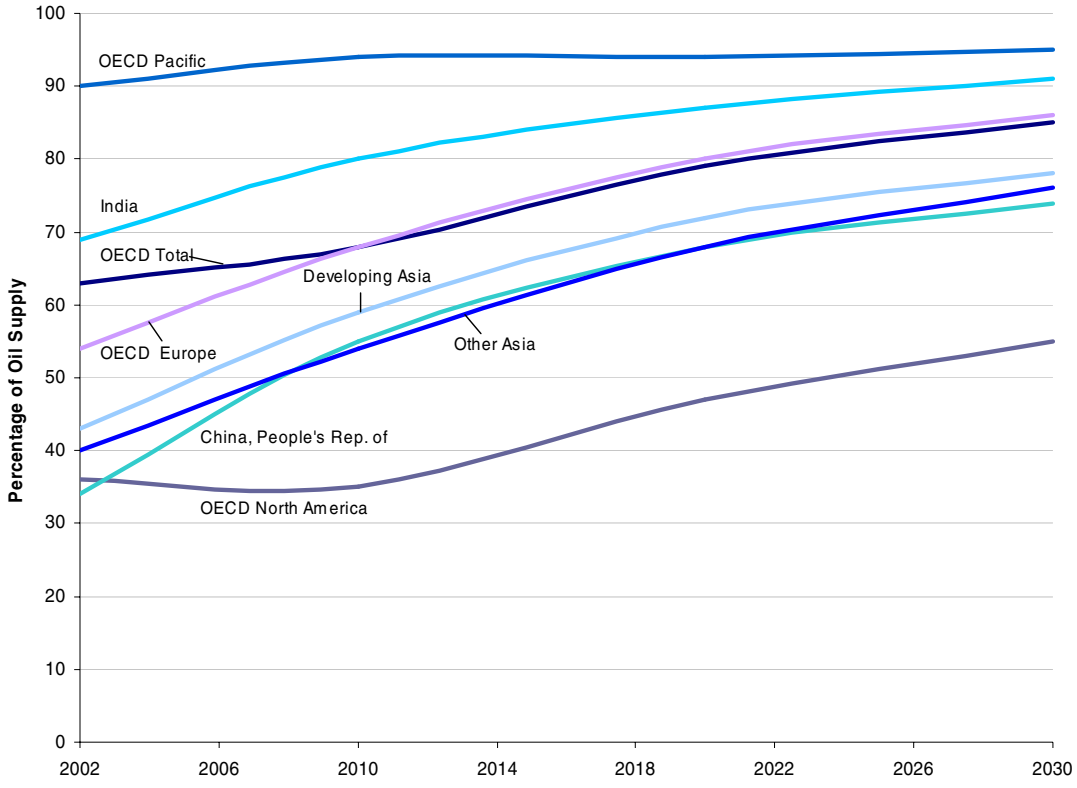
Source: British Petroleum (BP). 2006. Quantifying Energy. *BP Statistical Review of World Energy.* London: BP.

Figure 21: Fossil Fuel Consumption by Region, 2005



Source: British Petroleum (BP). 2006. Quantifying Energy. *BP Statistical Review of World Energy.* London: BP.

Figure 22: Dependence on Imported Oil by Region, 2002–2030

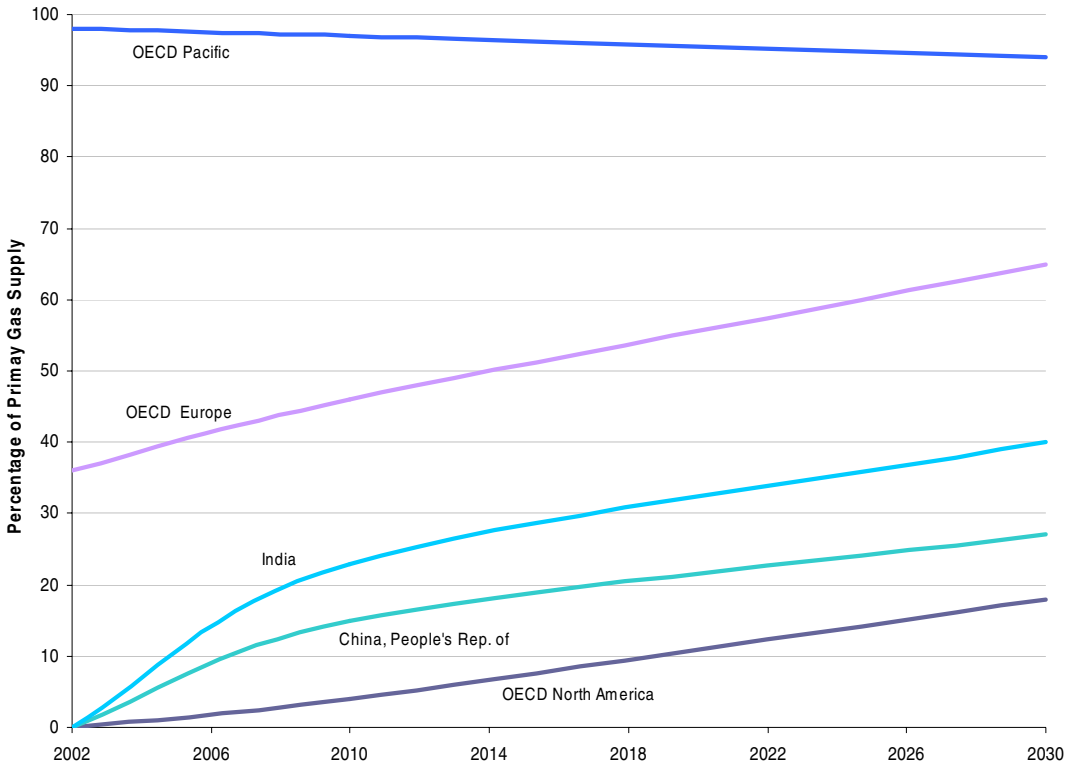


OECD = Organisation for Economic Co-operation and Development.
Source: IEA and OECD. 2004. *World Energy Outlook 2004.* Paris: IEA.

31. Natural gas production and trade is also set to increase dramatically, particularly in the form of liquefied natural gas (LNG) and with gas-to-liquids (GTL) projects also coming on-stream. Overall, the gas trade will triple over the projection period. OECD countries' gas imports will increase to a third of their consumption by 2030, up from the present 22%, most of which will come from the Middle East, the Russian Federation, and Central Asia. Countries such as the PRC and India will become increasingly dependent on imported gas, especially LNG (**Figure 23**). Gas consumption is also marked to grow rapidly in the producing countries of the Middle East as a deliberate strategy to free up increased oil volumes for export at prevailing high prices.

32. The volume of worldwide coal trade is proportionately small compared with actual consumption levels (13% in 2003), as most large consuming countries have their own substantial coal resources. The coal trade is expected to increase at an annual rate of 1.5% to 2030, with steam coal accounting for 72% of this by the end of the period, the remainder being coking coal. Australia and Indonesia will retain their ranking as the largest coal exporting nations, in that order, with Colombia and Viet Nam moving up to displace the PRC and South Africa in third and fourth positions, respectively. Both India and the PRC, despite being large producers of coal, will become major net importers by 2030.

Figure 23: Dependence on Imported Gas by Region, 2002–2030



OECD = Organisation for Economic Co-operation and Development.
Source: IEA and OECD. 2004. *World Energy Outlook 2004.* Paris: IEA.

Financial Requirements

33. In order to meet increased demand and sustain projected trade volumes and prices, a substantial investment of $105 billion per year—or a total of $3 trillion—will be required over the period 2003–2030 to maintain and expand the necessary oil production, handling, and

transportation infrastructure, such as well-head facilities, storage depots, tankers, pipelines, refineries, etc. A similar investment of $2.7 trillion will be required for natural gas, the bulk of it for exploration and development of new fields and the rest for infrastructure, such as liquefaction plants, pipelines, LNG tankers, and port terminals. Expanding coal trade will also require major investments in mining, ports, and rail transportation infrastructure. Additional electricity sector investments are estimated at $10 trillion, with $5.2 trillion of this in non-OECD countries. The share of renewable-based power generation in this would be $1.6 trillion, of which $1 trillion would be for technologies other than hydro—primarily wind power. Overall, cumulative energy sector investments could reach $17 trillion over this period, half of it in the developing world, which particularly in the latter case would present serious financing challenges.

34. Most of the investment in the oil and gas sector would be required in the Middle East and North African producing countries, which will see their share of world oil trade jump from 35% to 44% and natural gas exports quadruple over 2003–2030. The IEA predicts a major impact on the global energy balance should this region fail to double the existing investment levels in upstream facilities over the next decades, in which case oil prices would rise substantially with gas and coal prices following suit, thereby depressing world GDP growth. Oil price increases could also be triggered by stronger than expected economic growth, downward revision of regional reserve estimates, or geopolitical factors that disrupt production and supplies.

Technological Developments

35. In addition to projected fossil fuel costs, improvement in existing energy production and use methods, along with new and alternative technology development, will also impact future energy prices. Advances in oil and gas exploration and drilling techniques, efficiency and capital cost reductions in thermal and nuclear power generation equipment, increasing use of low-cost renewables and fuel cell technologies, and alternative resources such as biofuels and liquid fuels from natural gas and coal, would supplement existing supplies at competitive rates, while improvements in end-use efficiency—particularly in the transportation and electricity sectors, and fuel switching—particularly to pipeline, compressed, and liquefied natural gas—would help mitigate against fuel price increases. On the other hand, increasing commitment to environmentally cleaner methods, such as "clean" coal and higher-cost renewables, could drive the delivered cost of energy—particularly electricity—upwards.

2. The Asian Situation

36. As is evident from the preceding discussion, developing Asia is set to dominate global demand for additional energy resources and investments given its strong projected GDP growth rates, large population, and relatively low current per capita energy use base. The PRC will continue to exhibit the fastest growth rates, becoming the largest economy in the world by 2026, and with strong growth also projected for India which will move up to fourth position (behind the US and Japan), the two Asian giants will be responsible for a major part of incremental world energy demand. Compared with an average projected world GDP growth rate of between 3.2% and 3.8% per year, developing countries are expected to grow at 4.3%–5%, developing Asia up to 5.5%,[6] and the PRC and India at 5%–6% and 4.7%–5.4%, respectively (**Figure 9**) over the 2003–2030 period. Total primary energy demand will grow at up to 3.7% per annum for Asia,

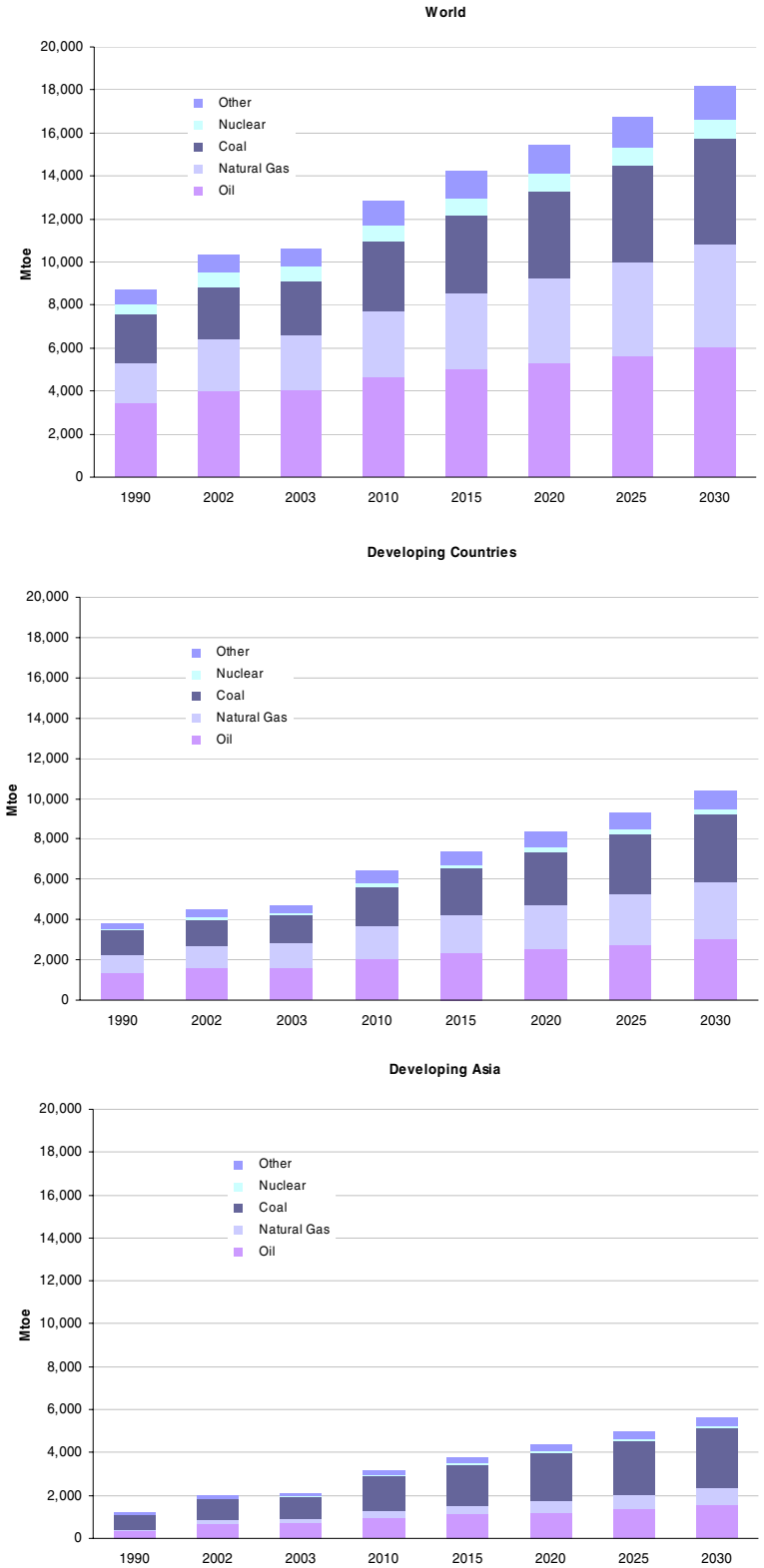
[6] In its latest forecast, for instance, the Asian Development Bank (ADB) has projected an annual average GDP growth rate for its developing member countries (DMCs) at 7.7% in 2006 and 7.1% in 2007 [ADB. 2006. Carbon Market Initiative: A Concept Paper, p. 12].

compared with 2.6%–3.0% for all developing countries and 1.6%–2.0% for the world, during the same interval. Developing countries will account for two thirds of the increase in primary energy demand in this period, while developing Asia alone will be responsible for almost half of it.

Primary Energy Mix and Regional Markets

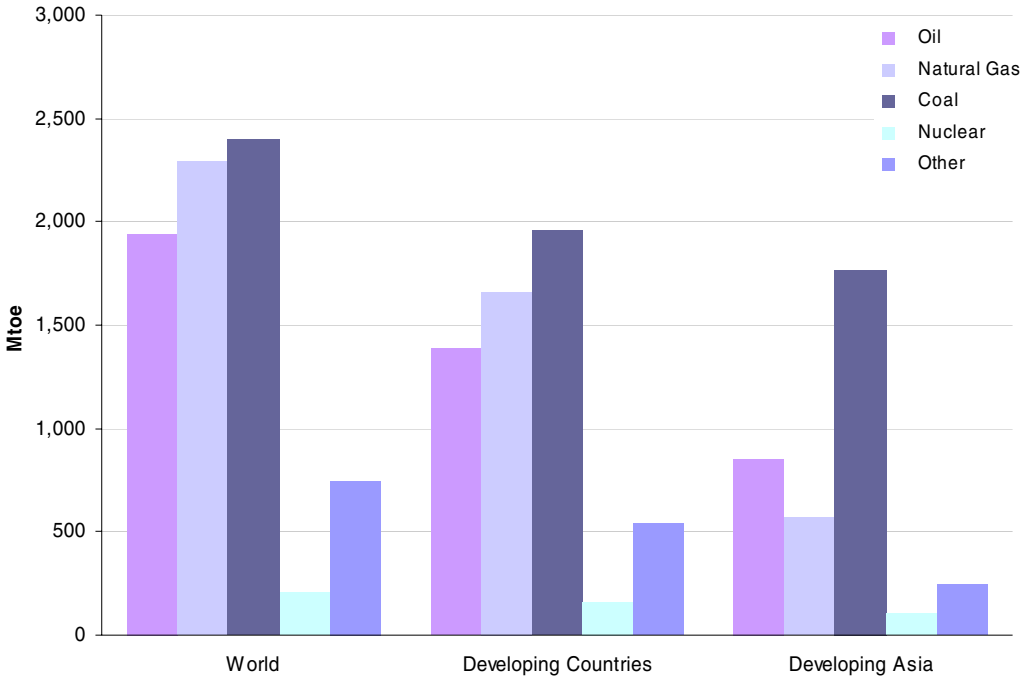
37. **Figure 24** shows the historical position as well as future trends in the mix of primary energy supply for Asia versus developing countries and the world. In all three cases, future increase in energy demand is largely to be met through higher fossil fuel consumption, with coal and oil use increasing proportionately faster than natural gas for Asia. A comparison of increase in demand by fuel between 2003 and 2030 is shown in **Figure 25**, from which it is clear that developing Asia would account for the bulk of the incremental coal demand in developing countries, which in turn would be 82% of the worldwide increase, but only one third of the developing country incremental gas demand and 62% of the additional oil consumption. For all fuels, developing countries will increase their share to at least 57% of world demand by accounting for 75% of the total increase in primary energy consumption. Developing Asia will consume three quarters of the additional global coal supplies, a quarter of new gas supplies and over half of new nuclear capacity, adding up to 62% and 47%, respectively, of developing countries and world incremental energy demand to 2030.

Figure 24: Primary Energy Mix, 1990–2030



Mtoe = million tons of oil equivalent.
Source: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

Figure 25: Share in Incremental Energy Demand, 2003–2030



Mtoe = million tons of oil equivalent.
Source: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

38. Altogether, developing Asia will represent almost a third of global primary energy demand by 2030. Energy consumption in these countries is expected to outstrip growth in indigenous supply well before 2030, although the region contains major energy resources, such as coal in the PRC, India, Pakistan, and Indonesia; oil in Indonesia and Malaysia; and gas in Central Asia and Brunei Darussalam. Oil production in the PRC is expected to decline, while that in Indonesia will remain largely flat.

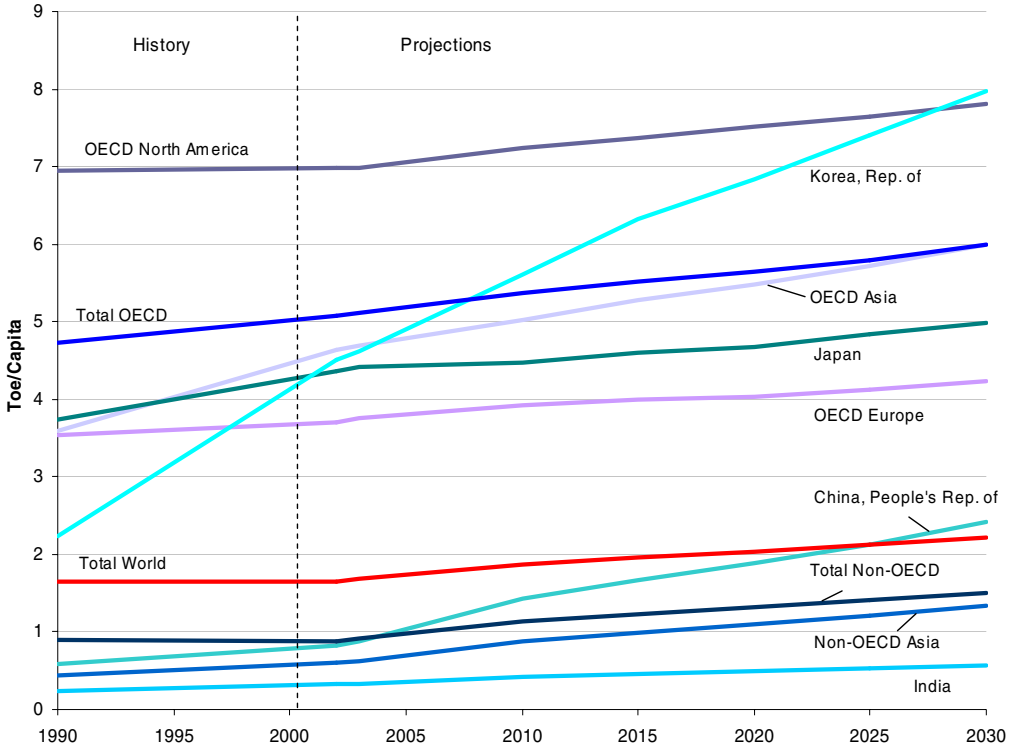
39. By 2030, developing Asia will be consuming over 30 mbpd of oil, or 26% of the world demand and more than that of the US and Canada combined. Almost all of the increase will be met through a doubling of imports, primarily from the Middle East. The region's dependence on imported oil will increase from 43% in 2002 to 78% in 2030 (**Figure 22**). The PRC, which became a net importer only in 1993, will be importing three quarters of its oil by 2030, and India over 90% of its requirements in that year. Natural gas demand in non-OECD Asia will likewise rise to anywhere from 24 to 30 tcf by the end of the period, depending largely on growth in imports by the PRC and India from other producers in the region and the Middle East (**Figure 23**). Developing Asia will be the world's largest coal market at 2.8 Gtoe, or 57% of the total, compared with 41% in 2003. The PRC and India will remain the largest producers and consumers, together accounting for 70% of the projected increase in world consumption. Coal use is also set to increase dramatically in some other fast growth Asian economies—such as Pakistan, based on its large untapped local deposits—in the face of high oil prices. Similarly, electricity consumption in Asia will rise rapidly, requiring 1,600 GW of new capacity or a third of the new worldwide installed base. The bulk of increased electricity generation will be fueled by coal and natural gas, although nuclear and renewable power are also predicted to increase their shares in several Asian countries. Traditional biomass use in developing Asia, especially for household applications such as cooking and heating where it accounts for three quarters of

current residential use, is not expected to decline appreciably, at least during the first half of the projection period and particularly in South Asia.

Energy Consumption, Access, and Costs

40. Asian countries differ markedly in terms of their levels of economic development and per capita energy use. For instance, compared with the world and OECD average per capita primary energy consumption of 1.67 toe and 5.07 toe, respectively, OECD Asia averaged a high 4.66 toe and developing Asia only 0.63 toe in 2003, as shown in **Figure 26** which also includes projections to 2030. Disparities within Asia can also be gauged in the diagram from the examples of Japan and India at the two extremes, and in projected energy use growth rates between the Republic of Korea and the PRC on the one hand and the rest of Asia on the other. By the middle of the projection period, the Republic of Korea will overtake the OECD per capita average and by its end even surpass OECD North America, whereas the PRC will exceed the world average beginning in 2025. However, the rest of developing Asia will remain well behind, at 60% of the world average and only 11% of the US per capita energy consumption figure in 2030. Average energy consumption rates will remain particularly low in South Asia, although growth will average a respectable 2% per year compared with the same rate for the Republic of Korea and 2.8% for developing Asia as a whole. This, of course, is because of the low starting levels for South Asia, which would require much more spectacular annual increases to catch up with other Asian regions. A comparison of per capita energy use in Asian countries is given in **Figure 27**, which shows a wide disparity resulting from their varying economic status, a situation likely to persist, qualitatively at least, to 2030.

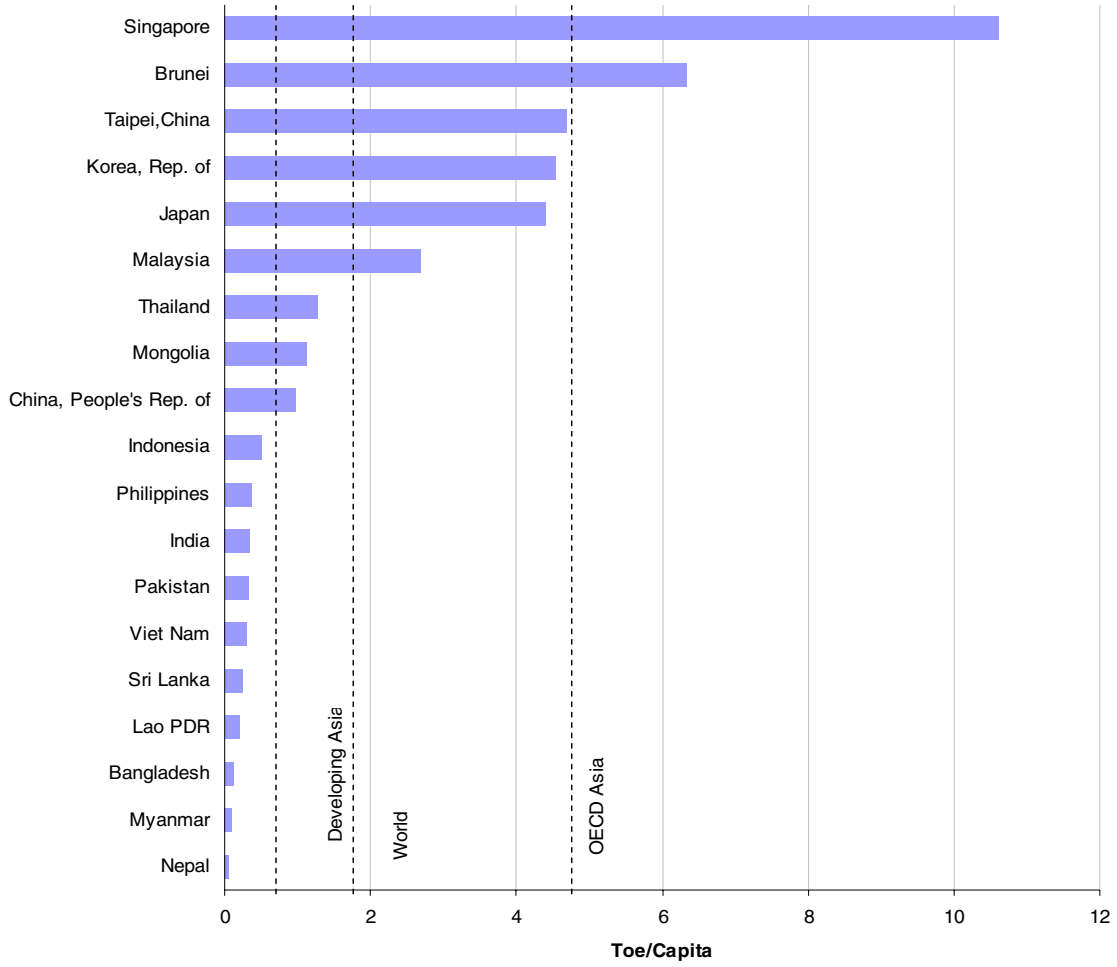
Figure 26: Primary Energy Use Per Capita, 1990–2030



OECD = Organisation for Economic Co-operation and Development; Toe = tons of oil equivalent.
Source: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE; www.iea.org.

41. Similarly, per capita electricity use ranged from an average of 909 kWh for developing Asia and 7,362 kWh for OECD Asia, compared with 7,683 kWh for OECD countries and 2,358 kWh for the world in 2003. Per capita electricity consumption in Asia is rising, albeit with large differences between different countries and with most of developing Asia falling below the world average (**Figure 28**). Trends in per capita electricity consumption, as shown in **Figure 29**, demonstrate two important features: the clustering of developed versus developing countries at the higher and lower ends of the graph, respectively, and that most of developing Asia, except for the PRC toward the end of the projection period, will remain well below 4,000 kWh/capita. The latter fact has important consequences, as will be explained subsequently in **Part II**. By 2030, India's per capita electricity consumption will not have caught up with the PRC's in 2003, a situation representative of other South Asian countries as well. Total installed electricity generation capacity in Asia compared with the rest of the world is shown in **Figure 30** for 2003 and 2030. The PRC and India will lead in world generation capacity expansion at almost 4.5% per year, with the rest of developing Asia following at 4% growth, compared with half that average for the world as a whole. By 2030, generation capacity in developing Asia will almost triple, accounting for 30%—or about 1,900 GW—of the world total of 6,350 GW, compared with 18% in 2003.

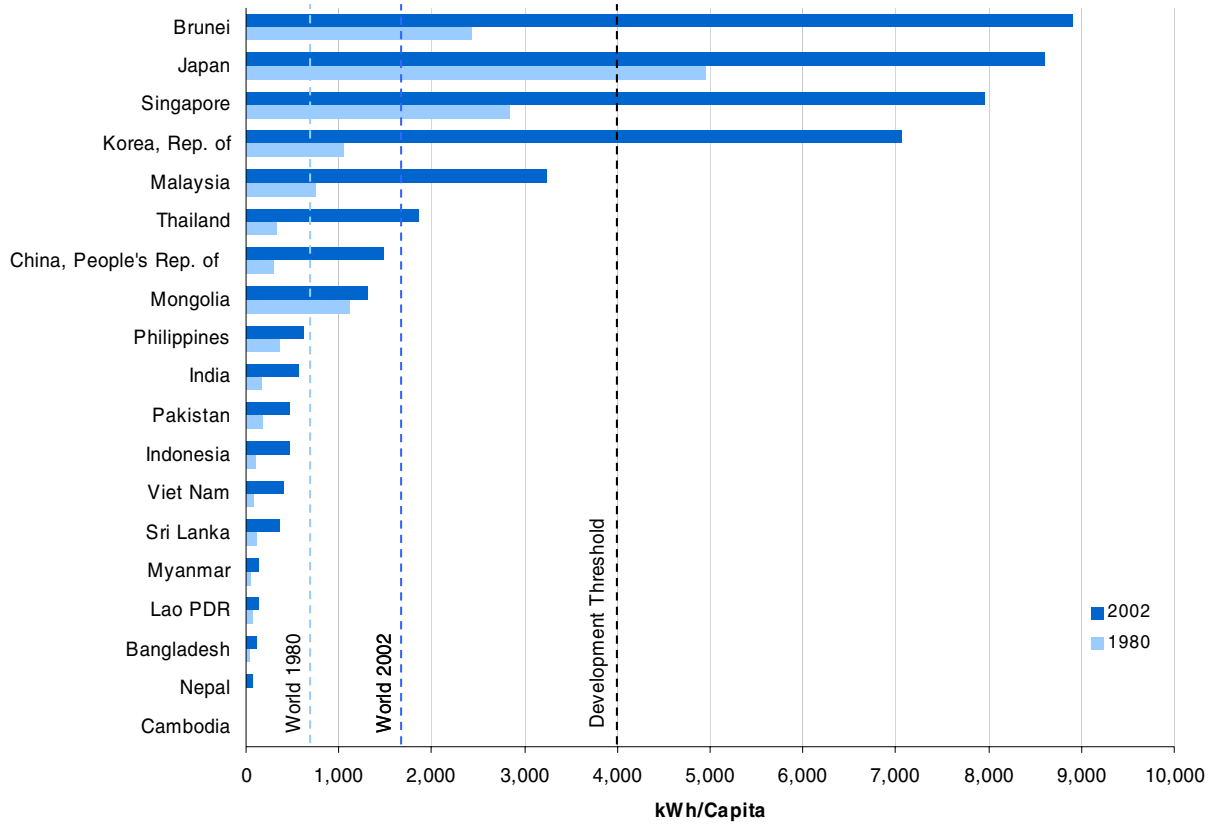
Figure 27: Energy Use Per Capita for Selected Asian Countries, 2003



Lao PDR = Lao People's Democratic Republic; OECD = Organisation for Economic Co-operation and Development; Toe = ton of oil equivalent.
Source: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

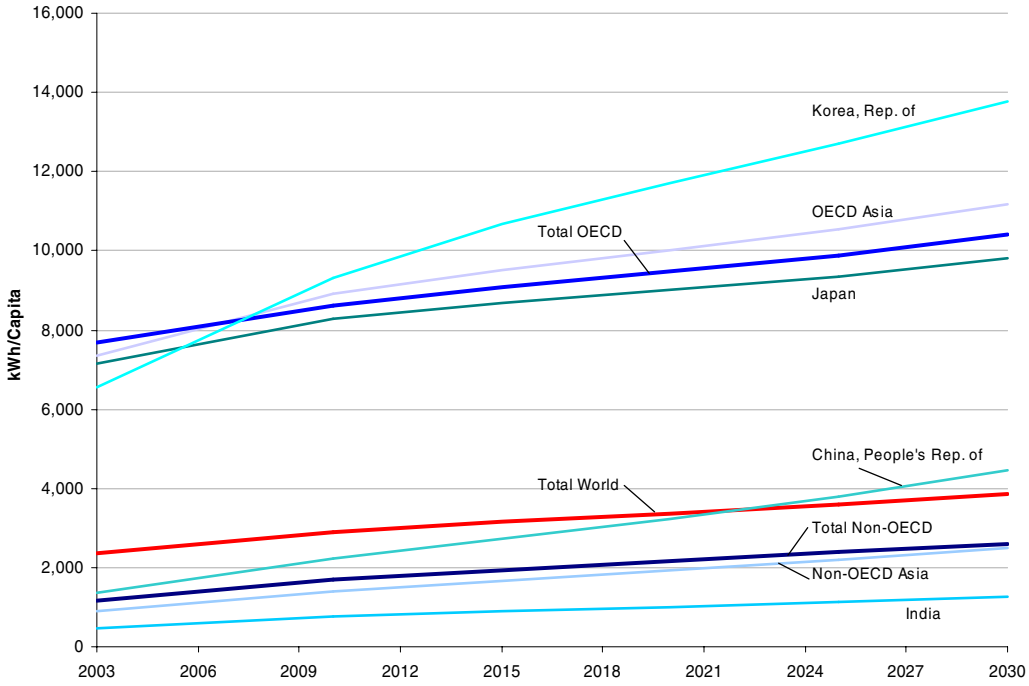
42. Energy use patterns in Asia are not only characterized by such wide contrasts between different regional economies, but also in terms of non-uniformity in access to modern energy supplies within most countries. **Figure 31** illustrates this in terms of percentage of national population connected to the electricity grid. Apart from a few affluent nations—notably including the PRC—most non-OECD Asian countries fall well short of providing universal access to their populations, with 30% of the region's total population lacking electricity. In addition, there are also wide variations in terms of the quality of power supplied, with the poorest often getting very little electricity, and usually only intermittently and of inferior quality. The data on such connections are also suspect, as utilities often classify even limited and rudimentary electricity service in the category of regular grid-supplied regions in order to meet government-specified rural electrification targets. Therefore, the situation is actually even less sanguine than such figures portray, with a significant number of the fraction with access to grid power unable to access it "on demand". Finally, fuel prices in general and electricity tariffs in particular constrain many of Asia's poor from properly utilizing even the limited energy supply options available to them, with consequent impacts on productivity, human development, and energy intensity—as shall be discussed next.

Figure 28: Electricity Consumption Per Capita in Asia, 1980 and 2002



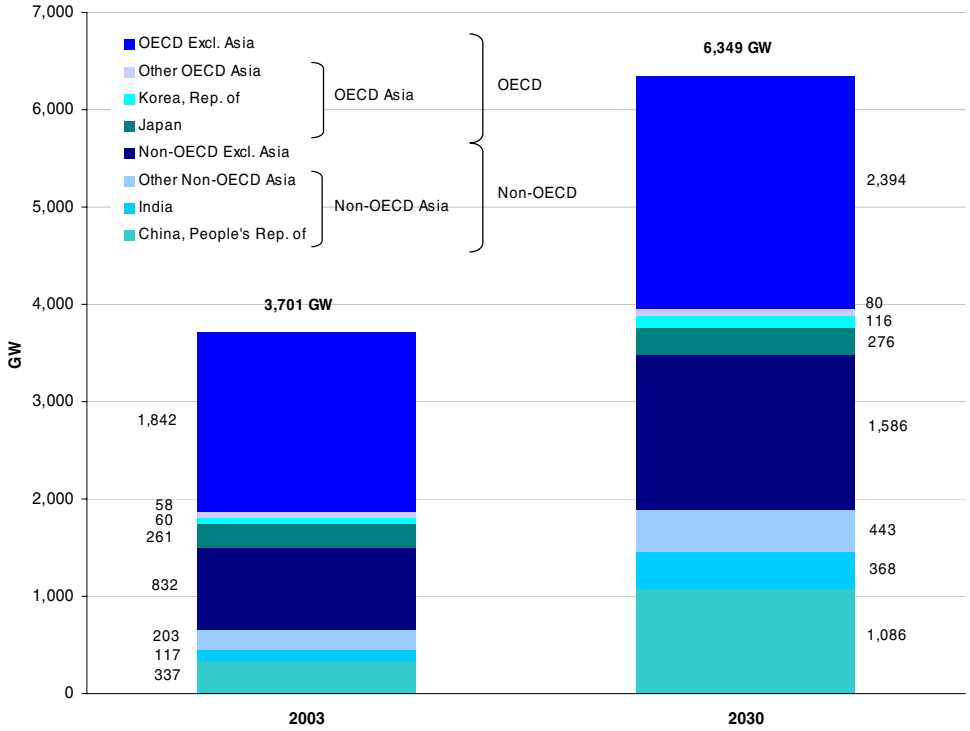
kWh = kilowatt-hour; Lao PDR = Lao People's Democratic Republic.
Source: UNDP. 2006. *Human Development Reports.* New York: UNDP. Available: http://hdr.undp.org/statistics/data.

Figure 29: Electricity Consumption Per Capita, 2003–2030



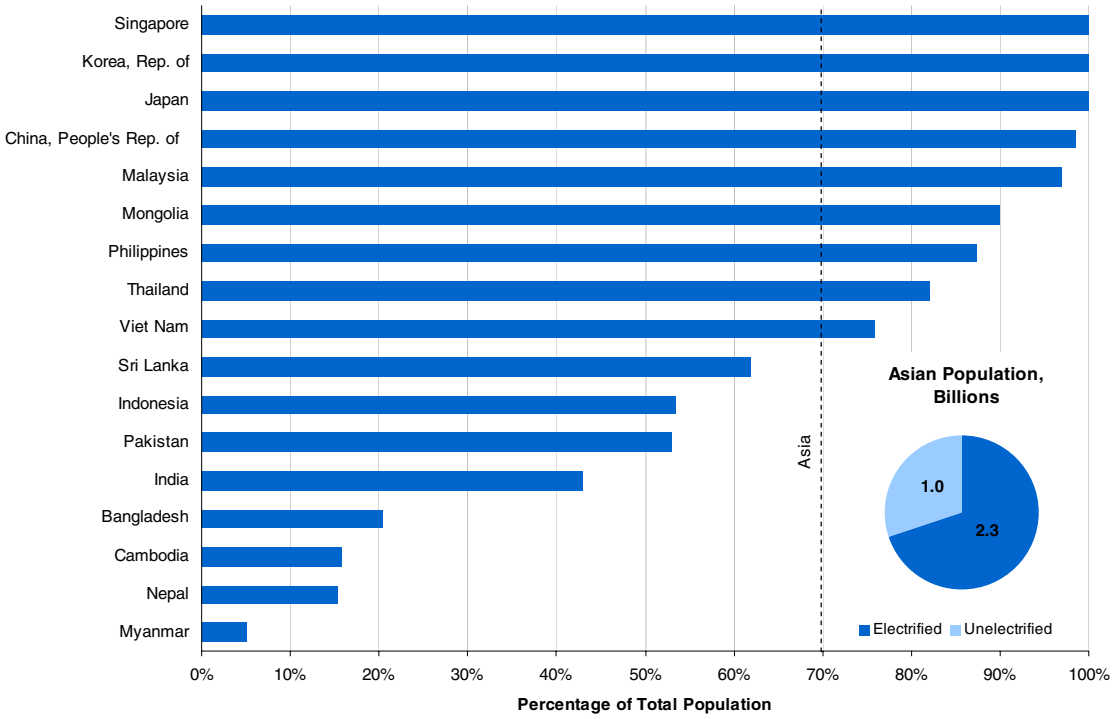
KWh = kilowatt-hour; OECD = Organisation for Economic Co-operation and Development.
Source: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

Figure 30: Installed Electricity Generation Capacity, 2003 and 2030



GW = gigawatt; OECD = Organisation for Economic Co-operation and Development.
Sources: US DOE/EIA. 2006. International Energy Outlook 2006. Report # DOE/EIA-0484 (2006). Washington, DC: EIA, US DOE.

Figure 31: Access to Electricity in Selected Asian Countries, 2000



Source: World Resources Institute (WRI). 2006. *Earth Trends: Environmental Information.* Washington, DC: WRI. Available: http://earthtrends.wri.org