

Chapter 2

Energy Consumption by End-Use Sector

In the IEO2006 projections, end-use energy consumption in the residential, commercial, industrial, and transportation sectors varies widely among regions and from country to country.

One way of looking at the future of world energy markets is to consider trends in energy consumption at the end-use sector level. With the exception of the transportation sector, which is almost universally dominated by petroleum products at present, the mix of energy use in the residential, commercial, and industrial sectors varies widely by region, depending on a combination of regional factors, such as the availability of energy resources, the level of economic development, and political, social, and demographic factors. This chapter outlines the *IEO2006* projections for delivered energy consumption by end-use sector in the OECD and non-OECD regions.

Residential Sector

Residential sector energy use is defined as the energy consumed by households, excluding transportation uses. The physical sizes of residential structures, their locations, and their designs are key factors in determining the amounts of energy used by their occupants. All else being equal, larger homes require more energy to provide heating, air conditioning, and lighting, and they tend to include more energy-using appliances, such as televisions and laundry equipment.

The type and amount of energy used by households vary from country to country, depending on income levels, natural resources, and available energy infrastructure. In general, typical households in the OECD countries use more energy than those in non-OECD nations, in part because they tend to include more energy-using appliances. Consequently, residential energy use per capita in 2003 was about 6 times higher in the OECD countries than in the non-OECD countries, averaging 24.9 million and 4.1 million Btu per person, respectively.

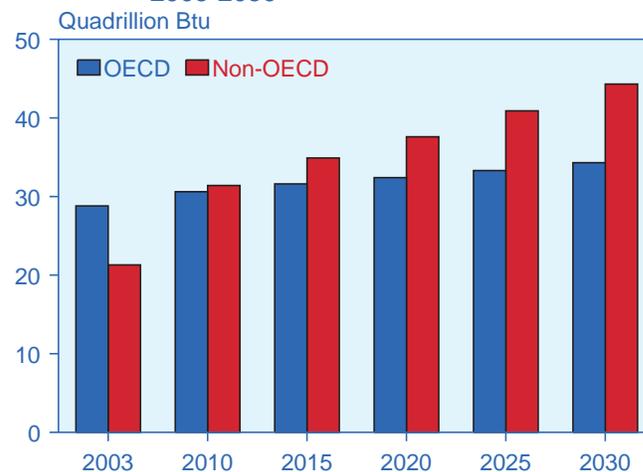
In the *IEO2006* reference case, the difference between OECD and non-OECD residential delivered energy consumption per capita narrows by about one-third from 2003 to 2030, as strong economic growth in the non-OECD countries results in improved standards of living and growing demand for household appliances, space heating and cooling equipment, and other energy-consuming devices. Even relatively small changes in per capita consumption will have a profound impact on total residential energy use in the non-OECD economies, which make up 80 percent of the world's population.

Whereas the OECD nations in total used more energy in 2003 than did the non-OECD nations, more rapid growth of residential energy consumption is projected for the non-OECD than for the OECD nations (Figure 19). Total non-OECD residential energy use surpassed the OECD total in 2010 and is 29 percent higher than the OECD total in 2030.

OECD Countries

Households in OECD nations use energy more intensively than those in non-OECD nations, primarily because of their higher income levels. Total residential electricity use in the OECD region increases by an average of 1.4 percent per year from 2003 to 2030 (Figure 20), accounting for about 80 percent of the total projected growth in OECD residential energy demand. As a result, increases in power plant capacity and corresponding fuel use are needed. The most rapid growth in residential energy use among the OECD nations is in Mexico, where real GDP grows at a rate that is nearly 60 percent faster than the OECD average. In OECD Asia, however, where population growth is expected to be minimal over the projection period, growth in residential energy demand is relatively slow.

Figure 19. OECD and Non-OECD Residential Sector Delivered Energy Consumption, 2003-2030



Sources: **2003:** Derived from Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2006).

Currently, the United States is by far the largest residential energy consumer in the world. For example, in 2003, residential energy use in all of OECD Europe was only about 7 percent greater than that in the United States. Moreover, with the U.S. population projected to grow at nearly 4 times the rate of OECD Europe's population from 2003 to 2030, residential energy consumption in the United States in 2030 is 6 percent greater than in OECD Europe.

Non-OECD Countries

Household energy use increases more rapidly in the non-OECD countries than in the OECD countries (Figure 20). Driven by robust economic growth and expanding populations, residential energy consumption in the non-OECD nations exceeds that in the OECD nations by nearly one-third in 2030. Real GDP in the non-OECD region as a whole is projected to grow by nearly 5 percent per year through 2030, and population by more than 1 percent per year on average. As a result, household energy use grows at a robust rate of 2.7 percent per year on average through 2030.

In China and India, the two fastest growing economies among the non-OECD countries in the *IEO2006* reference case, urbanization and population growth are expected to result in large increases in demand for residential energy services. China and India account for nearly one-half of the total increase in residential energy use in the non-OECD countries through 2030, as their economies continue to grow strongly over the projection period. In 2003, GDP in China and India combined was about 91 percent the size of U.S. GDP on a purchasing

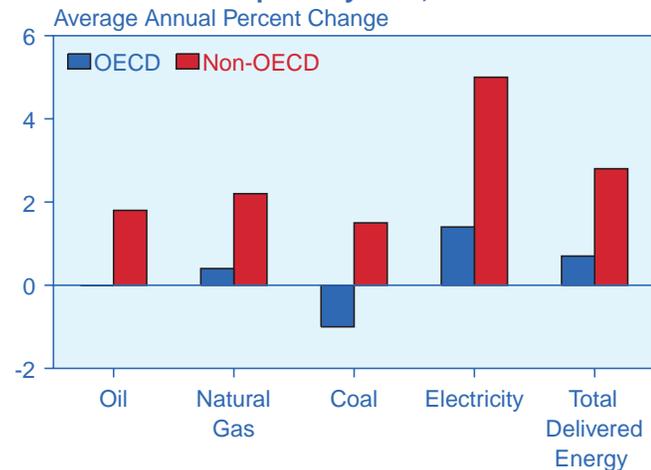
power parity basis; in 2030, their combined GDP is projected to be almost double that of the United States.

Commercial Sector

The commercial sector—often referred to as the services sector or the services and institutional sector—consists of businesses, institutions, and organizations that provide services, as opposed to those in manufacturing or agriculture. The sector encompasses many different types of buildings and a wide range of activities and energy-related services. Examples of commercial sector facilities include schools, stores, correctional institutions, restaurants, hotels, hospitals, museums, office buildings, banks, and even stadiums that hold sporting events. Most commercial energy use occurs in buildings or structures, including services such as space heating, water heating, lighting, cooking, and cooling. Energy consumed for services not associated with buildings, such as for traffic lights and city water and sewer services, is also categorized as commercial sector energy use.

Economic and population growth trends drive commercial sector activity and the resulting energy use. The need for services (health, education, financial, government) increases as populations increase. The degree to which these additional needs may be met depends in large measure on economic resources—whether from domestic or foreign sources—and economic growth. Economic growth also determines the degree to which additional commercial sector activities are offered and utilized. Higher levels of economic activity and disposable income lead to increased demand for hotels and restaurants to meet business and leisure requirements; for office and retail space to house and service new and expanding businesses; and for cultural and leisure space such as theaters, galleries, and arenas.

Figure 20. Growth in OECD and Non-OECD Residential Sector Delivered Energy Consumption by Fuel, 2003-2030



Sources: **2003:** Derived from Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2006).

OECD Countries

Commercial sector energy consumption in the OECD nations increases in the reference case by an average of 1.1 percent per year from 2003 to 2030 (Figure 21). Slow population growth in most of the OECD nations—along with continued efficiency improvements as energy-using equipment wears out and is replaced with newer, more efficient stock—moderates the projected growth; however, these factors are offset by economic growth that is expected to include continued growth in business activity, with its associated energy use, in areas such as retail and wholesale trade and business, financial, and leisure services. Although the fastest growth in commercial energy demand among the OECD economies is expected to be in the countries with the fastest GDP growth (Mexico and South Korea), the United States remains the largest commercial sector energy consumer in the OECD, accounting for one-half of the 24.7

quadrillion Btu of commercial energy use in the OECD as a whole in 2030.

Commercial electricity demand in the OECD nations grows by 1.8 percent per year from 2003 to 2030, with continued advances in technology and the introduction of new electronic appliances and equipment (Figure 22). Electricity delivered to commercial consumers in OECD countries, which totaled 8.5 quadrillion Btu in 2003, is 11.0 quadrillion Btu in 2015 and 13.8 quadrillion Btu in 2030, surpassing projected OECD residential electricity use of 13.1 quadrillion Btu by the end of the projection period. Natural gas continues to displace petroleum products and coal as the preferred commercial heating fuel in the OECD region.

Non-OECD Countries

Economic growth and commerce are expected to increase rapidly in the non-OECD nations, fueling additional energy demand in the services sector. Faster population growth is also expected, relative to that in the OECD countries, portending increases in the need for education, health care, and social services and the energy required to provide them. Under these circumstances, commercial sector energy use in non-OECD countries nearly doubles between 2003 and 2020, to 11.6 quadrillion Btu, and continues growing to 14.3 quadrillion Btu in 2030. Over the 2003 to 2030 period, commercial energy use in the non-OECD region increases at an average annual rate of 3.2 percent.

Electricity demand for commercial applications grows rapidly in the non-OECD nations as more clinics, schools, and business gain access to electricity. Annual

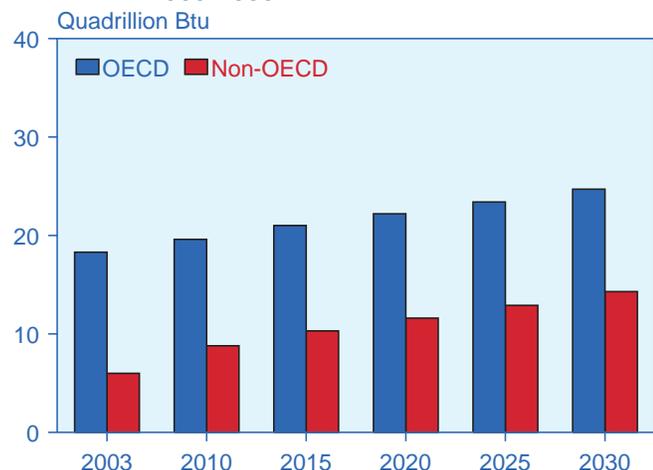
growth in commercial delivered electricity use averages 4.3 percent through 2030 (Figure 22), with projected consumption of 5.6 quadrillion Btu in 2015 and 8.8 quadrillion Btu in 2030. The largest increases in commercial electricity demand are projected for the nations with rapidly growing economies, particularly China and India, as their burgeoning economies foster increases in demand for services.

Increasing commercial activity is expected to lead to growth in demand for fossil fuels in the non-OECD nations. In the projections, commercial demand for natural gas grows by 3.0 percent per year from 2003 to 2015 and by 2.2 percent from 2003 to 2030, as several countries focus on expanding the infrastructure necessary for delivery of this relatively clean fuel. Commercial sector oil consumption in the non-OECD region increases from 1.4 quadrillion Btu in 2003 to 1.9 quadrillion Btu in 2015 and 2.3 quadrillion Btu in 2030, with more rapid increases in areas where the availability of natural gas is limited. Commercial sector coal use nearly doubles over the projection period in the non-OECD region, to 0.8 quadrillion Btu in 2030, with most of the growth occurring between 2003 and 2015. Coal remains an economically attractive choice for commercial water heating, space heating, and cooking in non-OECD countries in the projections, especially in China and India, which together account for around 80 percent of non-OECD commercial coal use from 2003 through 2030.

Industrial Sector

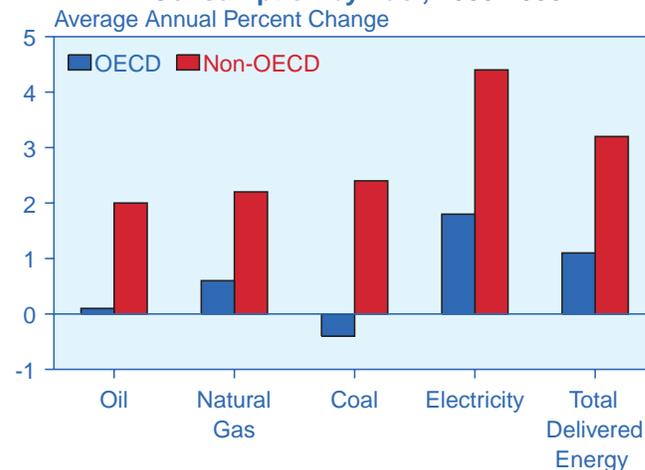
Energy is consumed in the industrial sector by a diverse group of industries—including manufacturing, agriculture, mining, and construction—and for a wide range of

Figure 21. OECD and Non-OECD Commercial Sector Delivered Energy Consumption, 2003-2030



Sources: **2003:** Derived from Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2006).

Figure 22. Growth in OECD and Non-OECD Commercial Sector Delivered Energy Consumption by Fuel, 2003-2030



Sources: **2003:** Derived from Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2006).

activities, such as process and assembly uses, space conditioning, and lighting. Industrial sector energy demand varies across regions and countries of the world, based on the level and mix of economic activity, technological development, and population growth, among other factors.

The industrial sector is the largest of the end-use sectors, consuming 50 percent of delivered energy worldwide in 2003, and industrial energy use is projected to grow more rapidly than energy use in the other end-use sectors. Worldwide, energy consumption in the industrial sector increases by an average of 2.4 percent per year from 2003 to 2030, as compared with 1.0-percent average annual growth in the world's population. Industrial energy consumption increases in all countries and regions; however, its growth rate in the OECD region—1.2 percent per year on average—is slower than the 3.2-percent average projected for the non-OECD region (Figure 23).

OECD Countries

Industrial sector energy use among the OECD nations increases by 1.2 percent per year, from 70.6 quadrillion Btu in 2003 to 97.8 quadrillion Btu in 2030. The United States accounts for approximately one-third of the OECD's total industrial energy consumption in 2030, and OECD Europe accounts for another one-third of the region's total, just as they did in 2003.

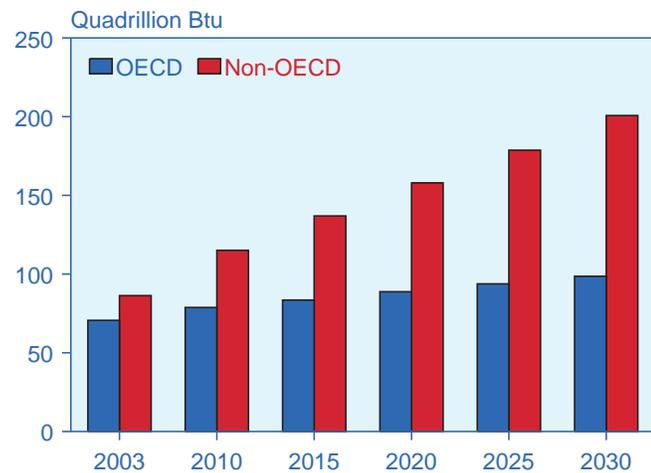
The OECD economies generally have more energy-efficient industrial operations and a mix of industrial output that is more heavily weighted toward non-energy-intensive sectors than do the non-OECD

countries. For example, in the United States, the manufacturing share of total economic output has declined steadily over the past two decades, while the output share for service industries (included in the commercial sector) has increased. Additionally, within the U.S. manufacturing sector, a smaller share of output has been produced by the heavy, energy-intensive industries (such as steelmaking). These general trends are projected to continue.

Similar developments are expected for the other OECD economies, as increasing international trade fosters a shift toward a less energy-intensive mix of industrial activity. For example, many of Japan's heavy industries are reducing their output as demand for energy-intensive materials increasingly is met by imports from China and other Asian countries. In the projections, the industrial sector in South Korea has the fastest energy consumption growth of the OECD countries, at nearly 2.5 percent per year. In Germany, a decline in industrial energy intensity in the early 1990s was largely the result of closures of heavy industries in the former East Germany after reunification. Much of the inefficient, energy-intensive eastern capacity in eastern Germany has already been shut down, but further improvements are projected as capital stock is replaced and modernized.

Electricity accounted for about 16 percent of OECD industrial sector energy use in 2003, and its share remains fairly stable throughout the projection period. Oil and natural gas were the most heavily used fuels in the OECD countries' industrial sectors in 2003, together accounting for two-thirds of the energy consumed in the sector. The two fuels maintain their overall share in 2030, but consumption of natural gas is grows almost twice as rapidly as that of oil (Figure 24). Coal makes up the bulk of the remaining industrial energy consumption, while renewables remain a minor energy source for the sector.

Figure 23. OECD and Non-OECD Industrial Sector Delivered Energy Consumption, 2003-2030



Sources: **2003:** Derived from Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2006).

Non-OECD Countries

Industrial sector energy consumption increases by 3.2 percent per year in the non-OECD countries between 2003 and 2030 (Figure 23). The non-OECD economies generally have higher industrial sector energy consumption relative to GDP than do the OECD countries. On average the ratio is 50 percent higher in the non-OECD countries. This is particularly true of Russia and the countries of non-OECD Europe and Eurasia, which still have energy-inefficient Soviet-era capital equipment. Per dollar of GDP, Russia's industrial sector consumes more than 9,000 Btu of delivered energy, and the non-OECD European and other Eurasian countries average more than 7,000 Btu, as compared with the overall non-OECD average of less than 4,000 Btu per dollar of GDP and the overall OECD average of around 2,500 Btu per dollar of GDP. As inefficient facilities in non-OECD

Europe and Eurasia are replaced with modern capacity, industrial energy intensities in the region are expected to decline more rapidly than in most of the rest of the world.

Of the non-OECD economies, China, the Middle East, and India have the most rapid increases in industrial sector energy consumption from 2003 to 2030. Whereas the economies of the OECD countries have largely moved away from heavy, energy-intensive industries (such as steel and cement) toward a greater emphasis on light manufacturing and service activities, the economies of many of the non-OECD countries and regions have growing energy-intensive, heavy manufacturing sectors.

Although electricity is expected to become an increasingly important component of industrial sector delivered energy demand in the non-OECD economies, oil, coal, and natural gas were the most heavily used fuels in 2003, and they are projected to remain so in 2030. Oil use in the non-OECD industrial sector increases at a slower rate than natural gas or coal use (Figure 24). The continued importance of coal in the non-OECD industrial sector is largely attributable to China, which accounts for two-thirds of industrial coal use in the non-OECD economies in 2030.

Transportation Sector

Transportation sector energy use includes fuels consumed for the purpose of moving people and goods by road, rail, and air. The road transport component consists of both light-duty vehicles (automobiles, sport utility vehicles, minivans, small trucks, and motorcycles, among other small vehicles) and heavy-duty vehicles (large trucks used for moving freight and buses for mass transit). Economic growth and population growth are key factors.

Petroleum products continue to dominate energy use in the transportation sector; and barring any widespread increase in the penetration of new technologies, the use of alternative fuels is expected to remain relatively modest through 2030. The *IEO2006* reference case projects a 1.4-percent average annual growth rate for transportation petroleum demand from 2003 to 2030. Much of the projected growth in demand for petroleum products in the transportation sector comes from the non-OECD economies (2.3 percent per year) as compared with the OECD countries (0.8 percent per year).

OECD Countries

In general, the transportation sector of the OECD economies is fully established, with extensive infrastructure that includes highways, airport facilities, and rail systems. Transportation energy demand in the OECD region grows at an average annual rate of 0.9 percent,

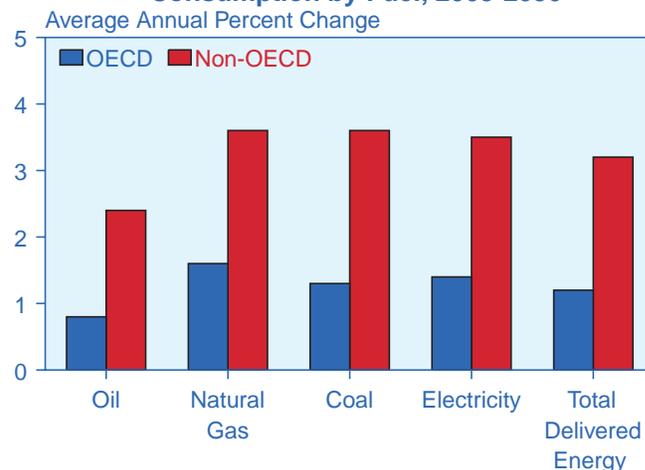
from 57.0 quadrillion Btu in 2003 to 64.1 quadrillion Btu in 2015 and 71.7 quadrillion Btu in 2030 (Figure 25).

In the United States, the transportation sector continues to account for more than one-fourth of the country's total energy consumption; and in the *IEO2006* reference case, U.S. transportation energy demand grows from 27.1 quadrillion Btu in 2003 to 33.1 quadrillion Btu in 2015 and 39.7 quadrillion Btu in 2030. The United States, currently the largest user of transportation energy among the OECD economies, accounts for 55 percent of total OECD transportation sector energy use in 2030.

Strong economic growth and a growing population are expected to increase the demand for larger, more powerful vehicles in the United States; however, advanced technologies and materials are expected to provide increased performance and size while improving new vehicle fuel economy. In the projections, the U.S. fuel economy standard for passenger cars is assumed to stay at the current level of 27.5 miles per gallon [1]. Not reflected in the projections is the new Corporate Average Fuel Economy (CAFE) rule, finalized in March 2006, which requires a higher fuel economy standard for light trucks, including the largest sport utility vehicles [2]. The new CAFE rule is expected to increase light truck fuel economy from an average of 20.7 miles per gallon in 2004 to an average of 24.1 miles per gallon for model years 2011 and beyond.

In contrast to the United States, transportation energy demand in OECD Europe is projected to remain fairly flat throughout the projection period. Low population growth, high taxes on transportation fuels, and environmental policies all contribute to the slow growth in the

Figure 24. Growth in OECD and Non-OECD Industrial Sector Delivered Energy Consumption by Fuel, 2003-2030



Sources: **2003:** Derived from Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2006).

OECD Europe transport sector. In fact, the transportation sector's share of total energy use in OECD Europe falls from 23 percent in 2003 to about 20 percent in 2030.

Petroleum products remain OECD Europe's largest source of energy for transportation. Although gasoline usage is expected to be higher than diesel fuel use in the OECD region as a whole, the product mix for road travel in OECD Europe is dominated by diesel fuel. In OECD Europe, the *IEO2006* projection assumes that most countries will keep taxes on diesel fuel lower than those for gasoline through 2030, encouraging a switch to diesel in the mid-term. Fast-paced growth in air travel is expected to translate to robust growth in demand for aviation fuels in the region.

In Japan, transportation energy use drops by an average of 0.4 percent per year, from 4.3 quadrillion Btu in 2003 to 4.2 quadrillion Btu in 2015 and 3.9 quadrillion Btu in 2030. The decrease is due mainly to Japan's aging population and low projected birth rate, in addition to the high taxes levied on motorists. Passenger cars in Japan are subject to numerous taxes imposed on acquisition, ownership, and operation, which are aimed at reducing oil imports and securing government funds for infrastructure projects.

In South Korea, transportation energy demand grows by 1.2 percent per year, from 1.8 quadrillion Btu in 2003 to 2.1 quadrillion Btu in 2015 and 2.4 quadrillion Btu in 2030. South Korea's total demand for oil grows at an average annual rate of 1.7 percent, from 4.5 quadrillion Btu in 2003 to 7.2 quadrillion Btu in 2030.

Non-OECD Countries

Energy demand in the non-OECD transportation sector as a whole grows at an average annual rate of 2.3 percent, from 28.9 quadrillion Btu in 2003 to 39.3 quadrillion Btu in 2015 and 53.3 quadrillion Btu in 2030 (Figure 25). As in the OECD economies, the growth in transportation energy is led by greater demand for air travel. Expanding ownership of private automobiles and an increasing role of trucking in freight transportation also play a significant role in the increase in energy demand. In 2003, the non-OECD economies accounted for about 34 percent of world energy use for transportation. In 2030, their share is 43 percent, as the gap between transportation energy consumption in the non-OECD and OECD economies narrows substantially over the projection period.

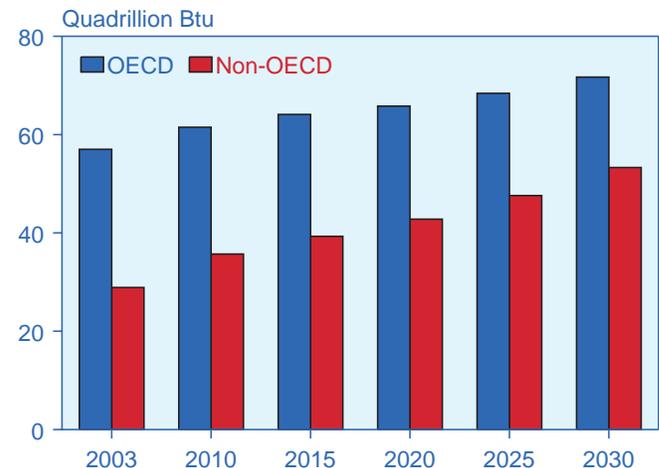
Non-OECD Asia is poised for strong and significant growth in transportation sector energy use, with China and India as the primary contributors to the growth. Strong growth is also projected for Asia's mid-sized markets, such as Thailand and Indonesia. In China and India combined, GDP expanded by an average annual 7.8 percent over the past decade, and their growth

remains strong in the mid-term projections, increasing by an annual average of 5.8 percent through 2030. The major hurdle facing China's and India's projected increases in the transportation energy demand is the need for increased infrastructure development. India has an effective and extensive rail system, but its highway system needs development. Work has started on a highway project to connect India's major cities, and it is expected to be completed in the next 5 years. Similar transportation infrastructure investments are occurring in China, as well. With these improvements, Asia's car ownership could exceed that of the United States by 2030 [3].

China's energy use for transportation grows by an average of 4.1 percent per year over the projection period, from 4.6 quadrillion Btu in 2003 to 7.8 quadrillion Btu in 2015 and 12.9 quadrillion Btu in 2030. Virtually all of the projected increase in transportation energy consumption is in the form of petroleum products. Road transport is the primary factor in China's growing demand for transportation fuels. There were 4.9 million automobiles in China in 2002, compared with 129.9 million automobiles in the United States [4]. Personal travel in China has soared in the past two decades, with passenger miles traveled increasing fivefold [5, 6]. Those trends continue in the projections.

In India, energy demand in the transportation sector grows at an average rate of 2.9 percent a year, from 1.4 quadrillion Btu in 2003 to 2.1 quadrillion Btu in 2015 and 3.0 quadrillion Btu in 2030. Transportation energy demand could grow even faster than anticipated in the *IEO2006* reference case, if all of the new highway projects currently under consideration in India are

Figure 25. OECD and Non-OECD Transportation Sector Delivered Energy Consumption, 2003-2030



Sources: **2003:** Derived from Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2006).

completed. Diesel usage in India is expected to be much higher than gasoline, in contrast to the United States. Diesel is often the preferred fuel for vehicles in developing economies. In the OECD countries, especially the United States and Europe, ultra-low-sulfur diesel is legislatively required for emission control purposes. Although there are similar regulations in many non-OECD countries, including in India, they are rarely enforced, and vehicles continue to burn less expensive, lower quality fuels. Transportation energy demand in the other non-OECD nations of Asia (the largest of which are Thailand, Indonesia, Malaysia, Singapore, Taiwan, and Hong Kong) grows by 2.3 percent per year, from 5.8 quadrillion Btu in 2003 to 7.7 quadrillion Btu in 2015 and 10.6 quadrillion Btu in 2030.

The Middle East region has a relatively small population and is not a major energy consumer but rather an exporter; however, rapid population growth is expected to result in more energy use for transportation in the future. The region's energy demand for transportation grows from 4.2 quadrillion Btu in 2003 to 5.2 quadrillion Btu in 2015 and 6.2 quadrillion Btu in 2030. Demand for transportation fuels in traditional exporting countries such as Saudi Arabia, Kuwait, Iraq, Oman, the United Arab Emirates, Yemen, and, most notably, Iran made the region a net importer of gasoline in 2003; however, that trend is expected to be reversed by 2010, when planned additions to refinery capacity come on line.

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