Chapter 8

Transportation sector energy consumption

Overview

In the *International Energy Outlook 2016* (IEO2016) Reference case, transportation sector delivered energy consumption increases at an annual average rate of 1.4%, from 104 quadrillion British thermal units (Btu) in 2012 to 155 quadrillion Btu in 2040. Transportation energy demand growth occurs almost entirely in regions outside of the Organization for Economic Cooperation and Development (non-OECD), with transportation demand roughly flat in OECD regions—largely reflecting different expectations for economic growth in developing regions compared with developed regions.

In 2012, OECD nations accounted for 55% of the world's total transportation energy consumption, and the non-OECD nations accounted for 45% (Figure 8-1). In 2020, the OECD and non-OECD shares of world transportation energy use are projected to be equal. Non-OECD demand for transportation fuels continues to outpace OECD demand, and in 2040 the non-OECD regions are expected to account for 61% of global transportation energy consumption. In the non-OECD regions, where 80% of the world's population resides, transportation energy demand nearly doubles, from 47 quadrillion Btu in 2012 to 94 quadrillion Btu in 2040, with an average annual increase of 2.5%. In several of the non-OECD regions, energy consumption in light duty vehicles accounts for the bulk of the increase in total transportation energy consumption, as economic growth raises standards of living and, in turn, the demand for personal transportation.

Transportation sector energy consumption by fuel

Worldwide, petroleum and other liquid fuels[326] are the dominant source of transportation energy, although their share of total transportation energy declines over the IEO2016 projection period, from 96% in 2012 to 88% in 2040. World transportation sector liquid fuels consumption grows by 36 quadrillion Btu in the Reference case projection, with diesel (including biodiesel) showing the largest gain (13 quadrillion Btu), jet fuel consumption increasing by 10 quadrillion Btu, and motor gasoline (including ethanol blends) increasing by 9 quadrillion Btu (Figure 8-2). Motor gasoline remains the largest transportation fuel, but its share of total transportation energy consumption declines from 39% in 2012 to 33% in 2040. From 2012 to 2040 the total transportation market share of diesel fuel (including biodiesel), which is the second-largest transportation fuel, declines from 36% to 33% and the jet fuel share increases from 12% to 14% in 2040.

The share of natural gas as a transportation fuel grows from 3% in 2012 to 11% in 2040. In 2012, pipelines accounted for 66% of transportation sector natural gas use, light-duty vehicles 28%, and buses 4%. As a result of favorable fuel economics, an increasing share of natural gas is used for transportation modes of travel other than pipelines. A strong increase is projected for the natural gas share of total energy use by large trucks in the Reference case, from 1% in 2012 to 15% in 2040. In addition, 50% of bus energy consumption is projected to be natural gas in 2040, as well as 17% of freight rail, 7% of light-duty vehicles, and 6% of domestic marine vessels.

Electricity remains a minor fuel for the world's transportation energy use, although its importance in passenger rail transportation remains high: in 2040, electricity will account for 40% of total passenger rail energy consumption. The electricity share of total

Figure 8-1. Delivered transportation energy consumption by country grouping, 2012–40 (quadrillion Btu)

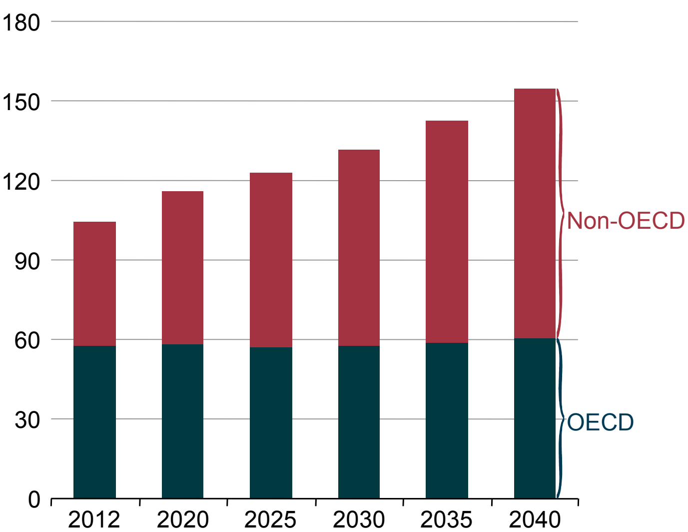
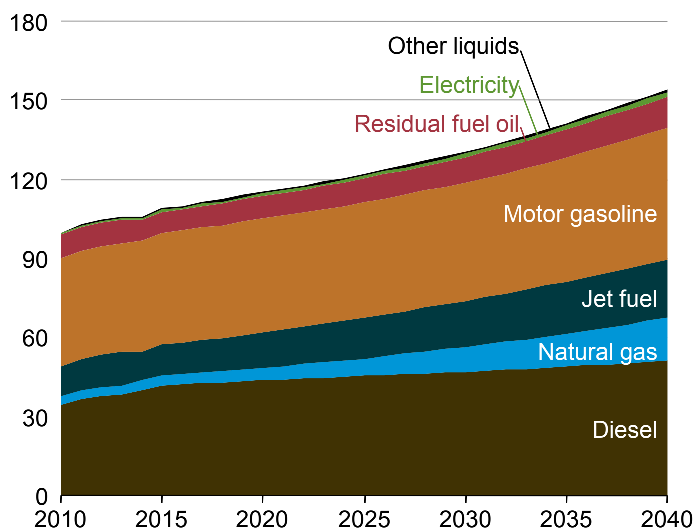


Figure 8-2. World transportation sector delivered energy consumption by energy source, 2010–40 (quadrillion Btu)



[326]Other liquid fuels include natural gas plant liquids, biofuels, gas-to-liquids, and coal-to-liquids.

light-duty vehicle energy consumption grows to 1% in 2040 in the Reference case, as increasing sales of new plug-in electric vehicles penetrate the total light-duty stock.

OECD transportation sector energy consumption

The OECD as a whole does not contribute to the worldwide growth in transportation fuels consumption in the IEO2016 Reference case. OECD transportation energy consumption patterns are already well established with slow economic and population growth rates and vehicle efficiency improvements, transportation energy use for the region as a whole does not increase over the 2012–40 projection period *(see "Motor vehicle fuel economy and emissions standards by country," below).* Almost no increase in transportation energy consumption is projected for the nations in the OECD Americas, as continued fuel economy improvements offset growth in vehicle miles traveled. In Japan, an aging and declining population results in lower transportation energy use, dropping by an average of 0.7%/year, with Japan's transportation energy consumption falling from 3.9 quadrillion Btu in 2012 to 3.3 quadrillion Btu in 2040. Most of the decline in Japan's transportation fuel use is for light-duty vehicles, with smaller decreases projected for freight trucks. The largest growth in OECD transportation energy use is projected for the Mexico/Chile region. In combination, delivered transportation energy use increases by 1.2%/year from 2012 to 2040 (Figure 8-3) compared to 0.2%/year for the OECD as a whole.

Motor vehicle fuel economy and emissions standards by country

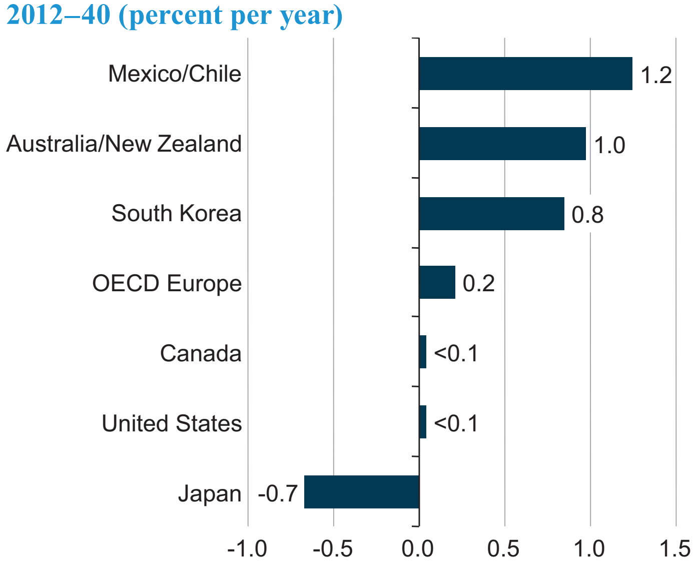
Nine countries and regions, which together account for 75% of global fuel consumption by light-duty vehicles, have adopted mandatory or voluntary standards for increasing fuel economy and reducing greenhouse gas (GHG) emissions. The intent and structure of the policies vary widely around the world. Because fuel economy and GHG emissions policies have large effects on fuel consumption, vehicle standards are among the most important components of future demand for liquid fuels.

One area of difference is the metric specified in the standard. Some standards focus on reducing GHG or carbon dioxide (CO2) emissions, some focus on improving fuel economy (or reducing fuel consumption), and others focus on combinations of the two objectives. The European Union (EU) and India have standards that specifically aim to reduce CO2 emissions. Canada's standard includes restrictions on all GHG emissions. Brazil and Japan have standards that aim to increase fuel economy, requiring light-duty vehicles to achieve specific miles-per-gallon ratings. China's standard requires light-duty vehicles to reduce fuel consumption per mile traveled. The United States and Mexico have both fuel economy and GHG standards, and manufacturers must satisfy both. South Korea's light-duty vehicle manufacturers can choose to meet either a fuel economy or a GHG emissions standard. In practice, however, the different metrics are related: improvements in fuel economy reduce CO2 emissions, and CO2 emissions are a subset of GHG emissions.

In addition, there are structural differences among the various vehicle standards. The United States, Canada, and Mexico have footprint-based corporate average fuel economy (CAFE) standards, which set GHG emissions targets (in Canada) or GHG emissions and fuel economy targets (in the United States and Mexico) based on vehicle footprint, calculated as wheelbase multiplied by average track width. The overall target for a specific manufacturer is determined by averaging the targets for the footprints of all the vehicles the manufacturer produces. Brazil, the EU, India, and South Korea have weight-based corporate average standards, which are similar to footprint-based standards but based on vehicle weight. China has a combination standard based on both vehicle weight class and corporate average fuel economy, which is more stringent than the weight-based corporate average standard alone; light-duty vehicle manufacturers in China must meet fuel consumption standards for each weight class, as well as an overall corporate average fuel consumption standard. Japan has a corporate average standard based on weight class, which requires each light-duty vehicle to meet the standard for its weight class rather than an overall standard for the manufacturer.

Fuel economy and emissions standards typically are applied to the vehicles that a company sells in a given country, rather than to all the vehicles it produces in a given country. For instance, U.S.-manufactured vehicles sold in Europe are required to meet European standards, and those sold in Japan are required to meet Japanese standards. As more countries adopt light-duty vehicle standards, differences among them are likely to persist because of variations in policy goals and consumer preferences across countries. Still, given the global nature of light-duty vehicle manufacturing, fuel economy is likely to increase for all new vehicles, and GHG emissions per mile traveled are likely to decrease.

Figure 8-3. Annual average growth in delivered transportation energy consumption by OECD region, 2012–40 (percent per year)



Non-OECD transportation sector energy consumption

Virtually all (94%) of the projected growth in world transportation energy use occurs in the developing non-OECD economies, where strong economic growth leads to rising standards of living that translate to demand for personal travel and freight transport to meet growing consumer demand for goods in non-OECD nations.

Non-OECD Asia

Much of the growth in non-OECD (and world) transportation energy use occurs in the emerging economies of non-OECD Asia. In particular, China accounts for the world's largest regional increment in transportation energy use, adding 14.3 quadrillion Btu of consumption over the 2012–40 projection period. China's consumption of transportation fuels increases on average by 2.7%/year from 2012 to 2040 (Figure 8-4), led by increases of 3.0%/year for heavy-duty vehicles that amount to 34% of the country's total increase in transportation sector energy consumption. Although energy consumption by light-duty vehicles increases by a more robust 3.5%/year, they account for only 27% of China's total increase in transportation fuel use.

Total transportation energy consumption in India also shows substantial growth in the IEO2016 Reference case, from 3.3 quadrillion Btu in 2012 to 10.9 quadrillion Btu in 2040, for an average annual increase of 4.4%. Fuel consumption by India's light-duty vehicles grows by 7.7%/year, accounting for 51% of the total increase in transportation energy use, largely as the result of a sizable increase in the country's middle class. Energy use by heavy-duty vehicles increases by an average of 4.4%/year from 2012 to 2040 and accounts for 18% of the total increase in India's transportation energy use.

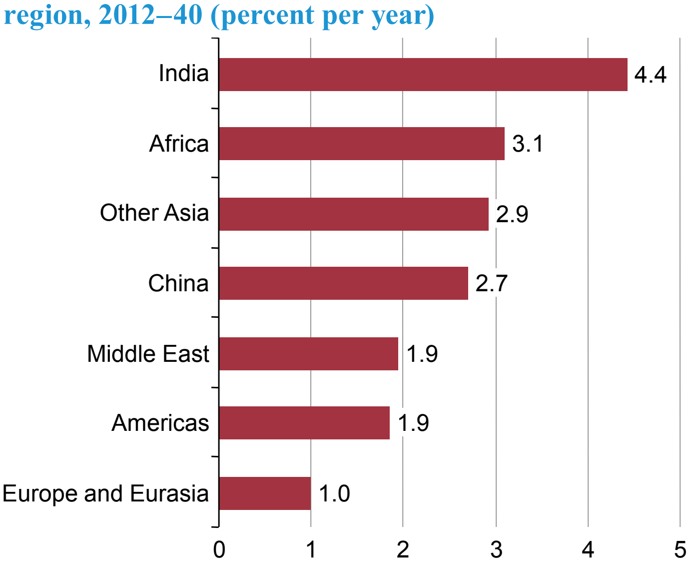
Like India and China, the other economies of non-OECD Asia also show significant growth in transportation energy demand from 2012 to 2040 in the IEO2016 Reference case. Total transportation energy consumption among the other non-OECD Asia nations grows from 7.6 quadrillion Btu in 2012 to 17.0 quadrillion Btu by 2040 in the Reference case, averaging 2.9%/year, with light-duty vehicle energy consumption rising by an average of 3.9%/year and accounting for 51% of the total increase in transportation energy consumption among the non-OECD Asian nations other than China and India. Significant increases in transportation energy use in these other non-OECD Asia nations are also projected for airline travel (17% of the total increase) and for heavy-duty trucks (7%).

Other non-OECD

Although the largest expansion in non-OECD transportation energy use occurs in non-OECD Asia, substantial increases are also projected for Africa, the Middle East, and the non-OECD Americas. In Africa, for instance, transportation energy consumption increases from 4.3 quadrillion Btu in 2012 to 10.1 quadrillion Btu by 2040, averaging 3.1%/year. On a regional basis, Africa has the world's highest projected growth in population (2.1%/year from 2012 to 2040) and robust projected growth in income (GDP rises by 4.8%/year). These demographic trends, combined with an underdeveloped transportation sector, explain the strong increase in transportation energy demand in the IEO2016 Reference case. The consumption of light-duty vehicle fuels increases by 3.9%/year in Africa, accounting for 52% of total transportation energy use in the region, as a result of a substantial increase in the number of middle-class consumers. Energy consumed by heavy-duty trucks increases by an average of 2.5%/year and accounts for 5% of Africa's total increase in transportation energy consumption.

In the non-OECD Americas, growth in transportation energy use is slower than in the non-OECD as a whole. In particular, transportation energy consumption in Brazil—the largest economy in the non-OECD Americas—increases by an average of 1.7%/year from 2012 to 2040, compared to the 2.5%/year increases projected for the non-OECD region as a whole. Fuel consumption in light-duty vehicles and heavy-duty trucks grows by similar rates in Brazil, with light-duty vehicles accounting for 31% of the total increase and heavy-duty trucks for 14%.

Figure 8-4. Average annual growth in delivered transportation energy consumption by non-OECD region, 2012–40 (percent per year)



Transportation sector energy consumption by mode

The transportation sector comprises both passenger and freight modes. The passenger modes include light-duty cars and trucks, buses, 2- and 3-wheel vehicles, airplanes, and passenger trains. The freight modes, which are used in the movement of raw, intermediate, and finished goods to consumers, include trucks (heavy-, medium-, and light-duty), marine vessels (international and domestic), rail, and pipelines.

Passenger or personal mobility-related fuel consumption accounted for 61% of total world transportation energy consumption in 2012. Among the personal mobility modes of transport, light-duty vehicles accounted for 44% of total world transportation energy use, followed by aircraft at 11%. Buses, 2- and 3-wheel vehicles, and rail accounted for 6% of total world transportation energy use. Freight modes accounted for the other 39% of total world transportation energy consumption. Freight trucks made up by far the largest share (23%) of total transportation energy use, followed by marine vessels (12%) and rail and pipelines (a combined 4%).

Worldwide, projected energy consumption for all transportation modes grows from 2012 to 2040. For passenger travel modes, total energy consumption rises by an average of 1.4%/year, from 63 quadrillion Btu in 2012 to 94 quadrillion Btu in 2040 (Figure 8-5). Light-duty vehicles show the largest absolute increase (15 quadrillion Btu) from 2012 to 2040 among the passenger modes of travel but the slowest growth (1.0%/year) among all the transport modes. World energy demand for aircraft increases by a total of 10 quadrillion Btu from 2012 to 2040, while the combined energy demand for buses, 2- and 3-wheel vehicles, and rail grows by 6 quadrillion Btu.

Total freight-related energy consumption grows by an annual average of 1.5% in the IEO2016 Reference case, from 40 quadrillion Btu in 2012 to 60 quadrillion Btu in 2040 (Figure 8-6)—slightly faster than the passenger modes. Energy consumption for freight trucks increases by a total of 13 quadrillion Btu from 2012 to 2040, followed by marine vessels at 6 quadrillion Btu and rail and pipelines combined at about 2 quadrillion Btu. The U.S. Environmental Protection Agency recently proposed a significant increase in fuel economy standards for heavy trucks. Should these proposed standards be adopted as final rules, they could significantly lower projections for diesel use in trucking. To the extent that these standards are implemented and affect trucks sold throughout the world, the reduction in diesel fuel use in trucking could be greatly magnified.

The growth trends for energy consumed by passenger modes in OECD and non-OECD regions from 2012 to 2040 differ considerably in the IEO2016 Reference case (Figure 8-7), with the OECD total declining by 1 quadrillion Btu and the non-OECD total increasing by 31 quadrillion Btu. The difference is explained in part by the larger increase in non-OECD passenger travel per capita from a low average base relative to most OECD nations. Non-OECD income (as measured by GDP) grows at a faster rate than in the OECD economies, and non-OECD consumers use more personal transportation as per-capita incomes grow. Although incomes also rise in the OECD nations, OECD levels of personal mobility are already relatively high, and transportation patterns and infrastructure are well established. In addition, the effects of increases in personal travel on OECD transportation energy consumption are tempered by rising energy efficiency, resulting in no growth in transportation energy consumption (see Figure 8-1). Although energy efficiency improvements also occur in the non-OECD regions, their impacts are overwhelmed by the increases in personal incomes and travel demand.

Figure 8-5. World transportation sector delivered energy consumption by passenger modes, 2012 and 2040 (quadrillion Btu)

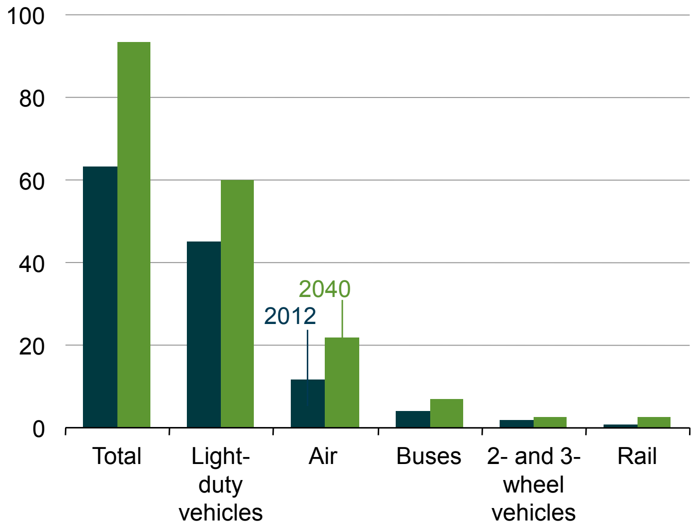


Figure 8-6. World transportation sector delivered energy consumption by freight modes, 2012 and 2040 (quadrillion Btu)

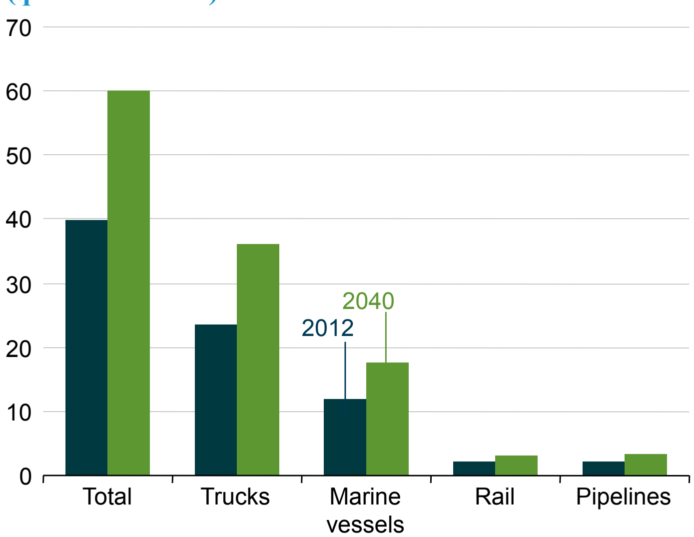
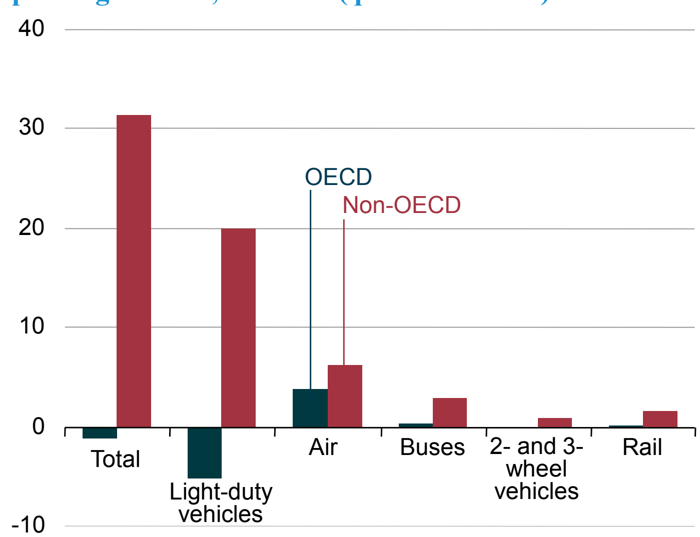


Figure 8-7. Change in OECD and non-OECD delivered transportation energy consumption by passenger mode, 2012–40 (quadrillion Btu)



World transportation energy use for passenger travel

The transportation of people and goods accounts for about 25% of total world delivered energy consumption (Figure 8-8). Passenger transportation—in particular, light-duty vehicles—accounts for most transportation energy consumption, with light-duty vehicles consuming more energy than all modes of freight transportation, including heavy trucks, marine, and rail combined.

The United States, where on-road passenger travel is especially prevalent, was the world's largest transportation energy consumer in 2012, the most recent year for which detailed international transportation data are available by mode. The United States consumed 26 quadrillion Btu of transportation energy in 2012, or 13 million barrels of oil equivalent per day (b/d), representing 25% of global transportation energy demand.

Major European countries (those in the OECD) and China are also major transportation energy consumers, at 19 quadrillion Btu and 13 quadrillion Btu, respectively, in 2012. In contrast to both the United States and OECD Europe, the largest share of China's on-road transportation energy use is for freight movement rather than passenger travel. Together, the United States, OECD Europe, and China account for 55% of world transportation energy consumption (Figure 8-9).

On-road use accounts for the largest share of transportation energy consumption in all regions of the world, but there is considerable variation across regions in the use of other modes of transportation. For instance, marine transport accounts for one-fourth of South Korea's total transportation energy use, reflecting the importance of marine transport in a peninsula nation whose economy relies heavily on exports, with major trading partners reached by maritime travel. In Australia, where regional air travel helps connect coastal population centers with sparsely populated regions, interior air travel accounts for nearly 20% of total transportation energy consumption, compared with 9% in the United States and 6% in China.

Global transportation energy consumption is dominated by two fuels: motor gasoline (including ethanol blends) and diesel (including biodiesel blends). Together, these two fuels accounted for 75% of total delivered transportation energy use in 2012. Motor gasoline is used primarily for the movement of people, especially by light-duty vehicles. Diesel fuel is used primarily for the movement of goods, especially by heavy-duty trucks. Jet fuel accounts for 12% of the world's transportation energy consumption, followed by residual fuel oil at 9%. Petroleum products account for the largest share of transportation energy use by far, while nonpetroleum fuels account for a small portion of the world energy mix, with natural gas and electricity together accounting for about 4% of the world's total transportation energy consumption.

Figure 8-8. World transportation energy consumption by mode, 2012 (quadrillion Btu)

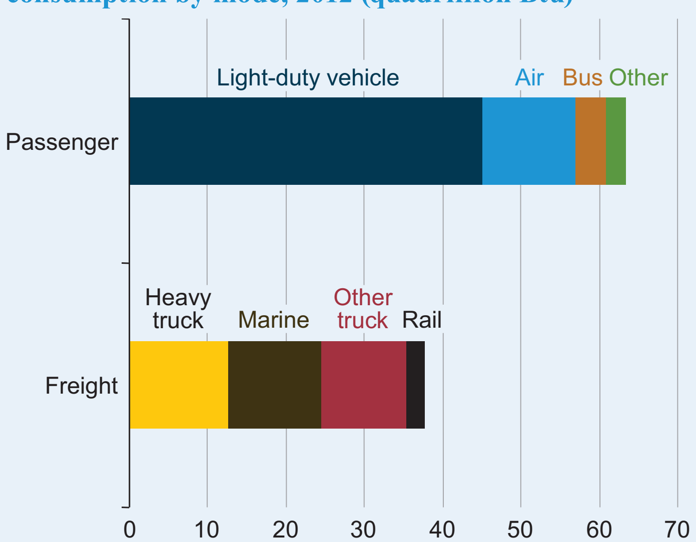
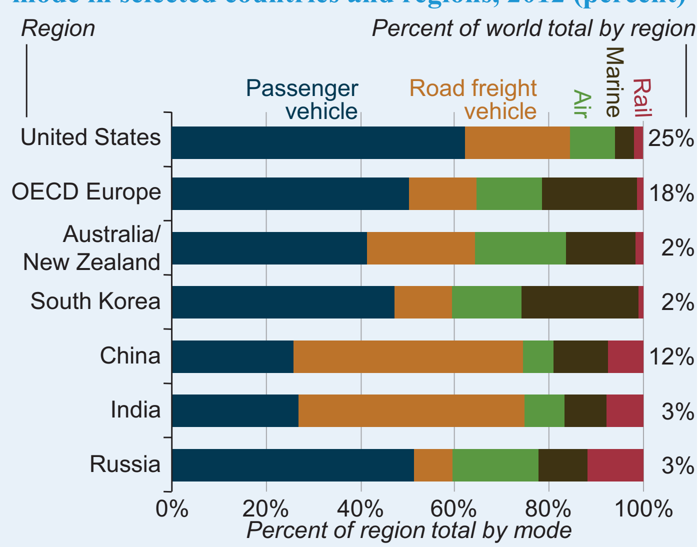


Figure 8-9. Transportation energy consumption by mode in selected countries and regions, 2012 (percent)

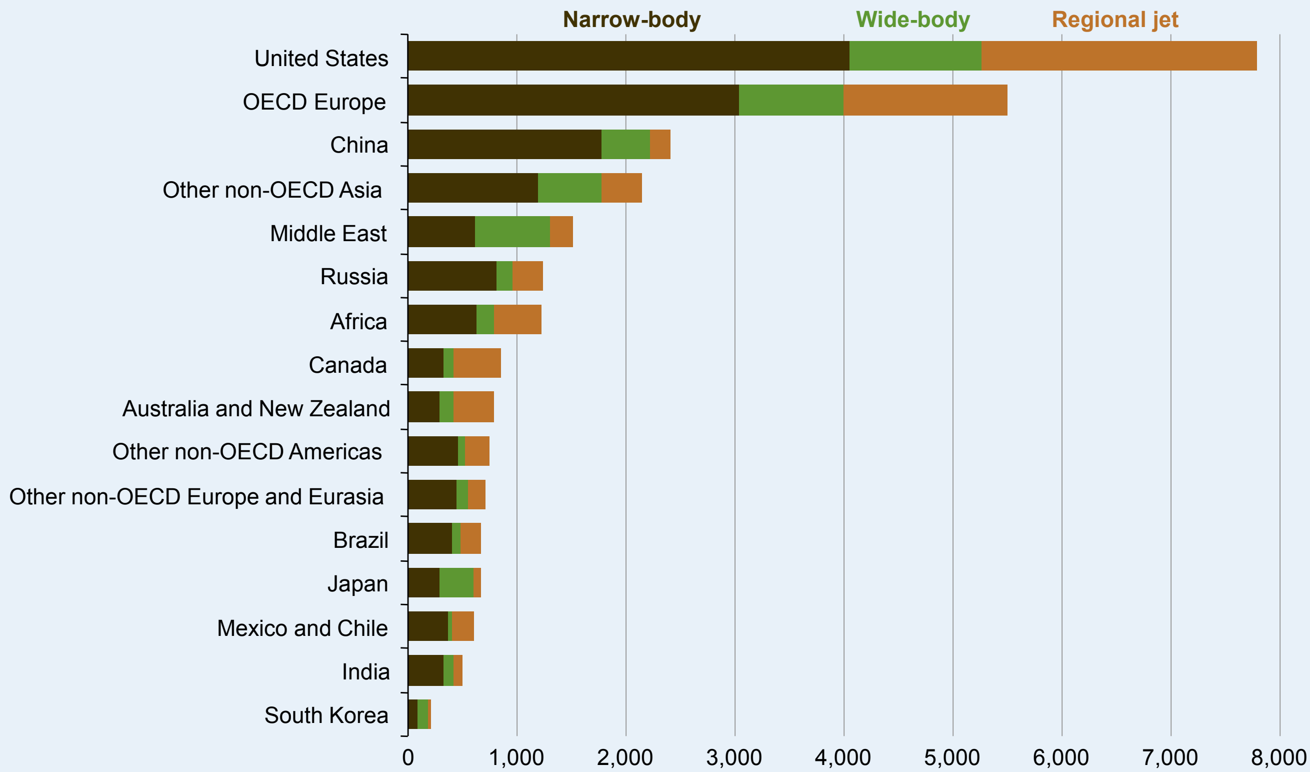


By mode, the largest increases in annual energy consumption for non-OECD passenger travel from 2012 to 2040 in the Reference case are for light-duty vehicles (20 quadrillion Btu) and aircraft (6 quadrillion Btu). In contrast, OECD energy demand for light-duty vehicles declines by 5 quadrillion Btu from 2012 to 2040, and annual energy demand for aircraft grows by only 4 quadrillion Btu.

World stocks of passenger jet aircraft

In 2013, three types of jet aircraft stock were available for national and international passenger travel: narrow-body, wide-body, and regional. Narrow-body jets are designed to carry between 120 and 180 passengers in two banks of seats separated by a center aisle; wide-body jets are designed for 200 to 500 passengers in three banks of seats; and regional jets are designed for 50 to 110 passengers. Nearly 28,000 passenger jets were in service in 2013, of which 55% were narrow-body, 19% were wide-body, and 26% were regional jets. By region, the United States had the largest stock of passenger jets (7,800), and OECD Europe had the second-largest (5,500). India and South Korea had the smallest numbers of passenger jets (499 and 209, respectively) (Figure 8-10).

Figure 8-10. World passenger jet aircraft stocks by region and type, 2013

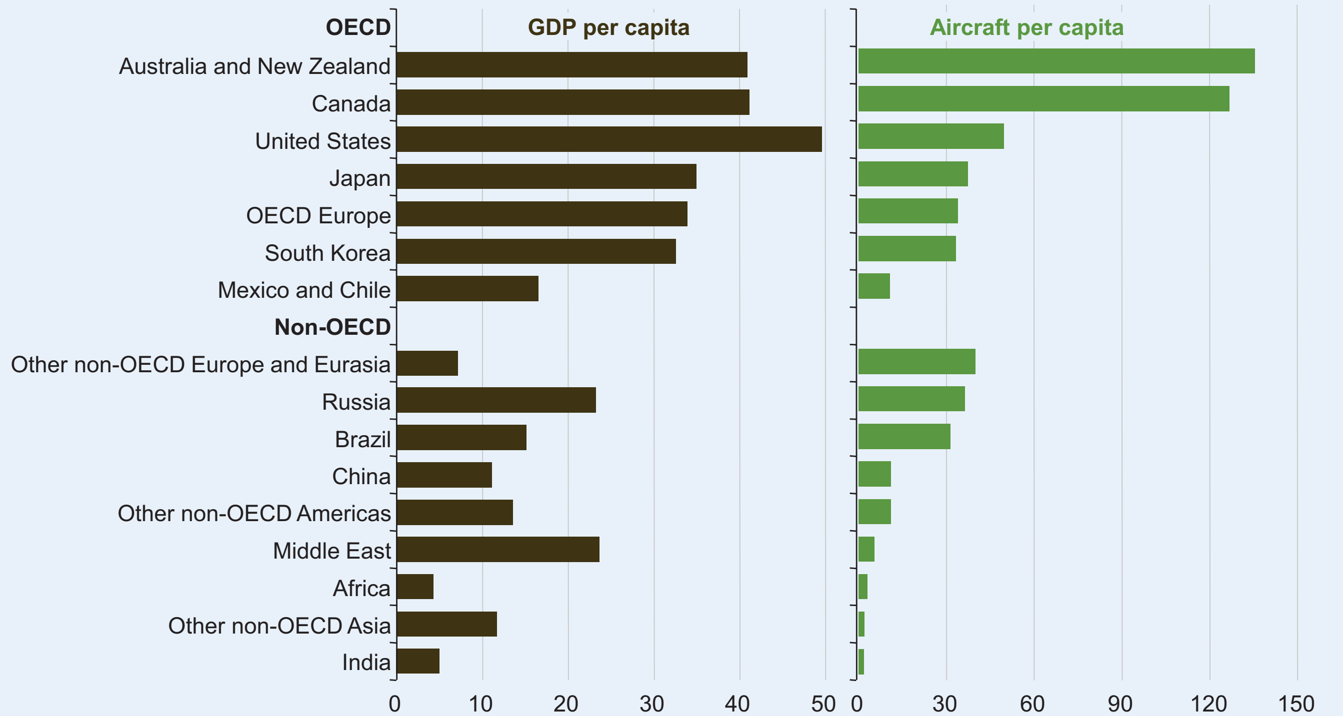


In most regions, narrow-body aircraft used for regional and transcontinental trips account for more than half of total aircraft fleets. In other regions—including the Middle East, Japan, and South Korea—air travel is dominated by long international flights, and wide-body aircraft account for approximately 45% of the totals. In regions where short-range trips are more prevalent, regional jets make up the largest shares of aircraft fleets, including 46% in Australia/New Zealand and 51% in Canada.

Ratios of aircraft stock per million people also differ by region. In general, the more developed OECD regions, with higher gross domestic product (GDP) per capita, also have higher aircraft-to-population ratios than the non-OECD regions (Figure 8-11). The Australia/New Zealand region has the world's highest aircraft-to-population ratio (136 aircraft per million people), Canada has the second-highest (127), and the United States has the third-highest (50) despite its higher GDP per capita. In Japan (with GDP per capita of $35,000), the ratio of aircraft per million population is estimated at 37, while for Canada (with GDP per capita of $41,000), the ratio is estimated at 127. Africa, India, and other non-OECD Asia have the lowest aircraft-to-population ratios at 3, 2, and 2, respectively. These numbers underscore the significant uncertainty associated with projecting future trajectories of aircraft-to-population ratios in non-OECD countries as they develop economically, which may reflect regional characteristics such as geography and population despite having similar GDP per capita.

(continued on page 133)

Figure 8-11. Gross domestic product (thousand 2010 dollars per person) and aircraft stock per capita (aircraft per million people) by region, 2013



In contrast to passenger modes of travel, the trends in freight modes in the OECD and non-OECD regions are similar (Figure 8-12). In both, energy consumption increases for all freight modes from 2012 to 2040, with the largest increases for trucks and international maritime vessels. Production and consumption of goods worldwide are an integral part of globalized supply chains, including trade in intermediate products for global production processes, which in large part is made possible by containerized transportation shipping and advances in information technology.

Transportation sector travel demand

Rising global incomes increase the demand for personal mobility, measured as passenger-miles per capita, in all the world regions, with different rates of increase depending on current income levels (Figure 8-13) and travel patterns, as well as the unique nature of regional geographies. Consequently, the rates of increase in travel demand per capita vary across the OECD and non-OECD regions (Figure 8-14).

Figure 8-12. Change in OECD and non-OECD delivered transportation energy consumption by freight mode, 2012–40 (quadrillion Btu)

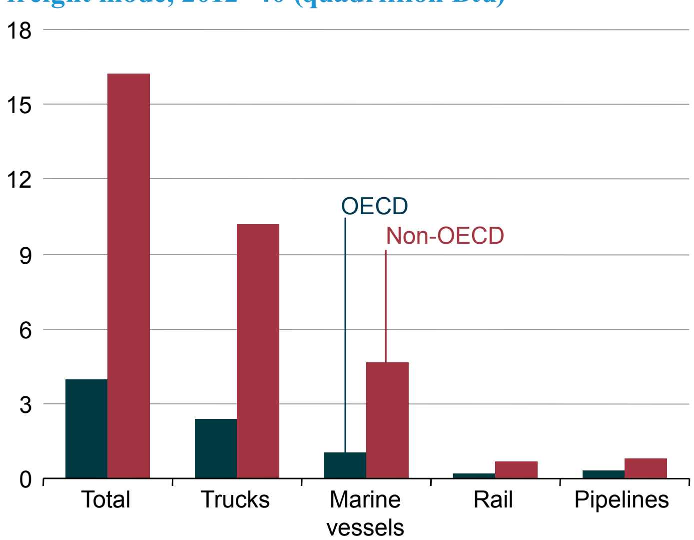
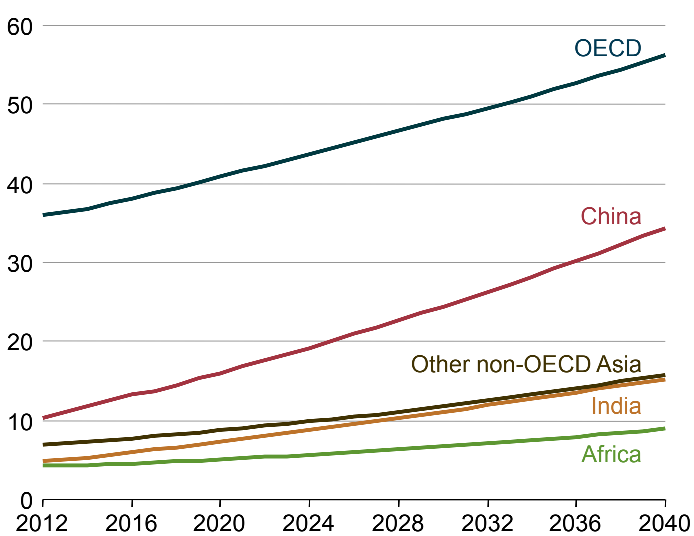


Figure 8-13. GDP per capita in selected regions and countries, 2012–40 (thousand 2010 dollars)



OECD regions are, for the most part, economically developed and thus have higher levels of personal mobility than the non-OECD countries. In the IEO2016 Reference case, OECD passenger travel per capita (including light-duty and 2- and 3-wheel vehicles, buses, and passenger rail but excluding aircraft) increases from 9.1 thousand passenger-miles/person in 2012 to 10.3 thousand passenger-miles/person in 2040, while average GDP per capita rises from about $36,000/person to $56,500/person (in inflation-adjusted real 2010 U.S. dollars). In comparison, average non-OECD GDP per capita rises from an average of $8,500/person in 2012 to $20,800/person in 2040, and passenger travel per capita rises from 2.1 thousand passenger-miles/person in 2012 to 4.9 thousand passenger-miles/person in 2040.

As a result of the increase of more than 100% in non-OECD travel demand from 2012 to 2040, the region's total energy use for passenger travel in 2040 is more than 50% higher than the OECD total, compared with about two-thirds the OECD total in 2012. In 2012, non-OECD Asia (including China and India) and Africa accounted for two-thirds of the world's total population; in 2040, they are projected to account for more than 70%. Accordingly, the two regions have the largest projected growth in transportation energy consumption in the IEO2016 Reference case. In China, delivered energy consumption in the transportation sector increases by 2.7%/year from 2012 to 2040, compared with 0.2%/year for the OECD as a whole. Per-capita income in China in 2040 is similar to the OECD level in 2012, but China's transportation sector delivered energy consumption in 2040, at 18.9 million Btu/person, is less than half the OECD's 2012 average of 46.2 million Btu/person.

The transportation modes used for passenger travel also reflect the effects of rising incomes and the current difference between OECD and non-OECD personal mobility choices. In 2012, more than 80% of OECD personal travel was by light-duty vehicle, compared with 41% of non-OECD personal travel. In the non-OECD region, a substantial portion of personal travel was by bus (35%), passenger rail (13%), and 2- and 3-wheeled vehicles (11%). Non-OECD economic growth and rising incomes in the IEO2016 Reference case lead to a higher overall rate of light-duty vehicle ownership (measured as the number of light-duty vehicles per 1,000 people), but in 2040 the non-OECD rate of light-duty vehicle ownership remains well below the OECD rate (Figure 8-15). Still, the light-duty vehicle share of non-OECD passenger travel rises to more than 50% in 2040, primarily at the expense of buses and 2- and 3-wheeled vehicles (Figure 8-16). Consequently the difference in light-duty vehicle travel shares between the OECD and non-OECD regions is narrowed, but not eliminated, by 2040 in the Reference case.

Demand for personal travel by aircraft, measured as revenue passenger-miles, shows a similar trend. As GDP and personal incomes increase, business and personal airline travel also increase. Relatively wealthy OECD consumers already have a much higher rate of airline travel per capita than do non-

Figure 8-14. Passenger travel per capita in selected regions and countries, 2012–40 (thousand passenger-miles)

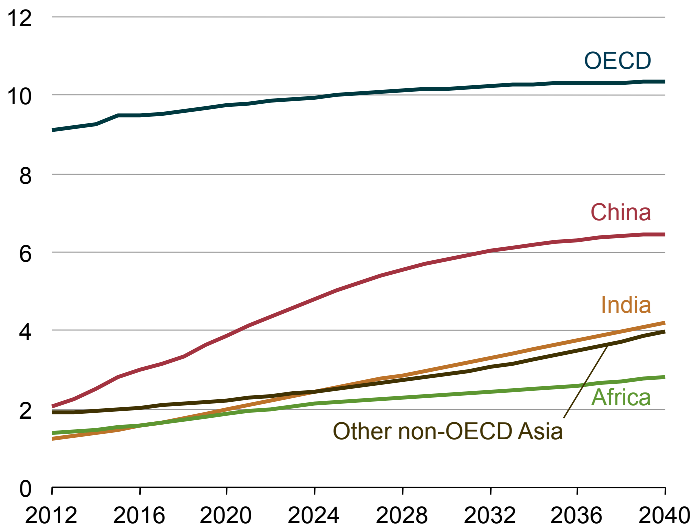


Figure 8-15. Light-duty vehicles per thousand people in selected regions and countries, 2012–40

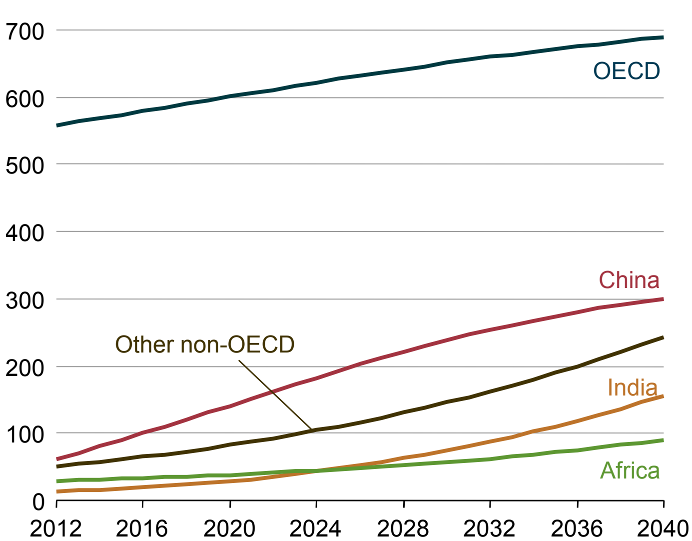
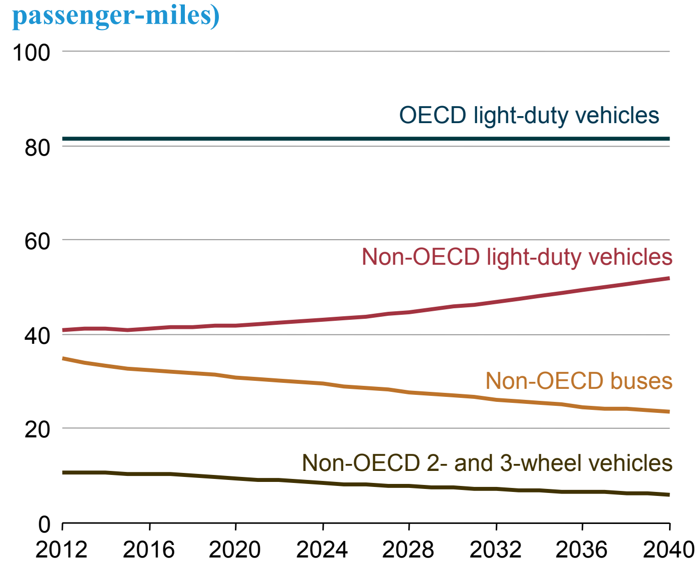


Figure 8-16. OECD and non-OECD passenger travel by selected travel modes, 2012–40 (percent of total passenger-miles)

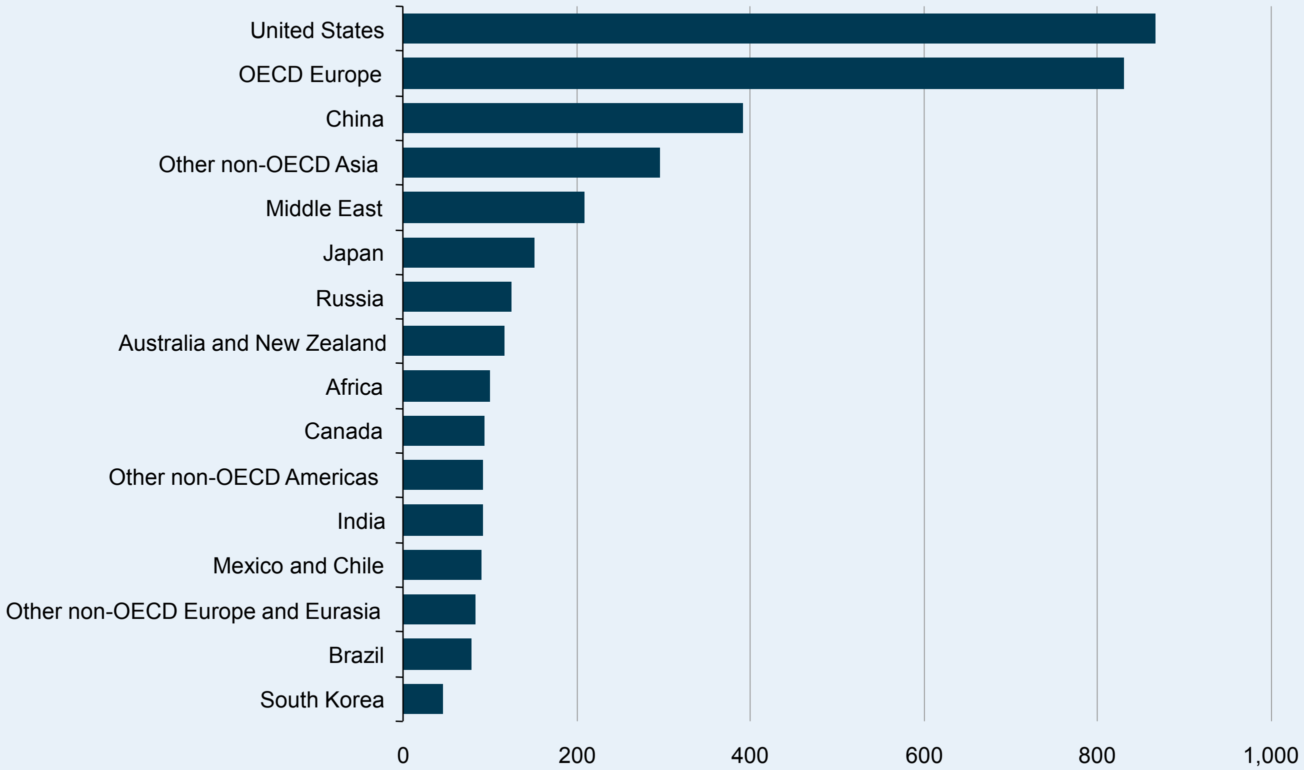


OECD consumers. Demand for airline travel increases in the Reference case for both the OECD and non-OECD regions, with more rapid growth among the non-OECD regions.

Variations in air passenger travel by region and income level

Air passenger travel, measured by revenue passenger-miles (RPM),[327] includes both domestic travel (within a single IEO2016 region) and international travel (across regional boundaries). In 2013, the United States led the other world regions in total passenger air travel with 866 billion RPM, followed by OECD Europe with 830 billion RPM and China with 392 billion RPM. South Korea had the lowest passenger air travel, at 47 billion RPM (Figure 8-17).

Figure 8-17. World air passenger travel by region, 2013 (billion revenue passenger-miles)



In 2013, the United States had the world's highest level of domestic air passenger travel and the second-highest level of international air passenger travel, at 603 billion RPM and 264 billion RPM, respectively. OECD Europe, with the second-highest level of domestic air passenger travel, at 435 billion RPM, was first in international travel with 395 billion RPM. China was third in domestic air passenger travel, at 281 billion RPM, and other non-OECD Asia was third in international air travel, at 170 billion RPM (Figure 8-18).

As gross domestic product (GDP) per capita increases in the world regions, RPM per capita also increases. Regions with the highest GDP per capita (United States, Australia/New Zealand, and Canada) also have the highest RPM per capita. In 2013, Australia led the world with 4,200 RPM per capita, followed by the United States and Canada, both with 2,700 RPM per capita. Regions with lower GDP per capita also have lower RPM per capita (Figure 8-19). India and Africa had the lowest GDP per capita in 2013 ($5,000 and $4,300, respectively) and the lowest rates of personal air travel (less than 100 RPM per capita).

In general, regions with higher GDP per capita have higher RPM per capita. The regions with the world's top five highest RPM per capita are comparatively wealthy OECD regions—the United States, Australia and New Zealand, Canada, OECD Europe, and Japan. Most of the non-OECD regions have RPM per capita below 500. In the coming years, as strong economic growth in many non-OECD regions results in higher GDP per capita, personal air travel also is expected to rise, as suggested by the trends shown in Figure 8-19. As average GDP per capita in the non-OECD regions approaches $40,000, travel behavior can be expected to vary—as it has in the OECD regions—adding uncertainty as to whether future trends in RPM per capita for the non-OECD regions will more closely resemble RPM per capita for Australia or for the United States.

(continued on page 136)

[327] The value for revenue passenger-miles is calculated as: *(number of revenue-paying passengers) × (total miles traveled).*

Figure 8-18. World domestic and international air passenger travel by region, 2013 (billion revenue passenger-miles)

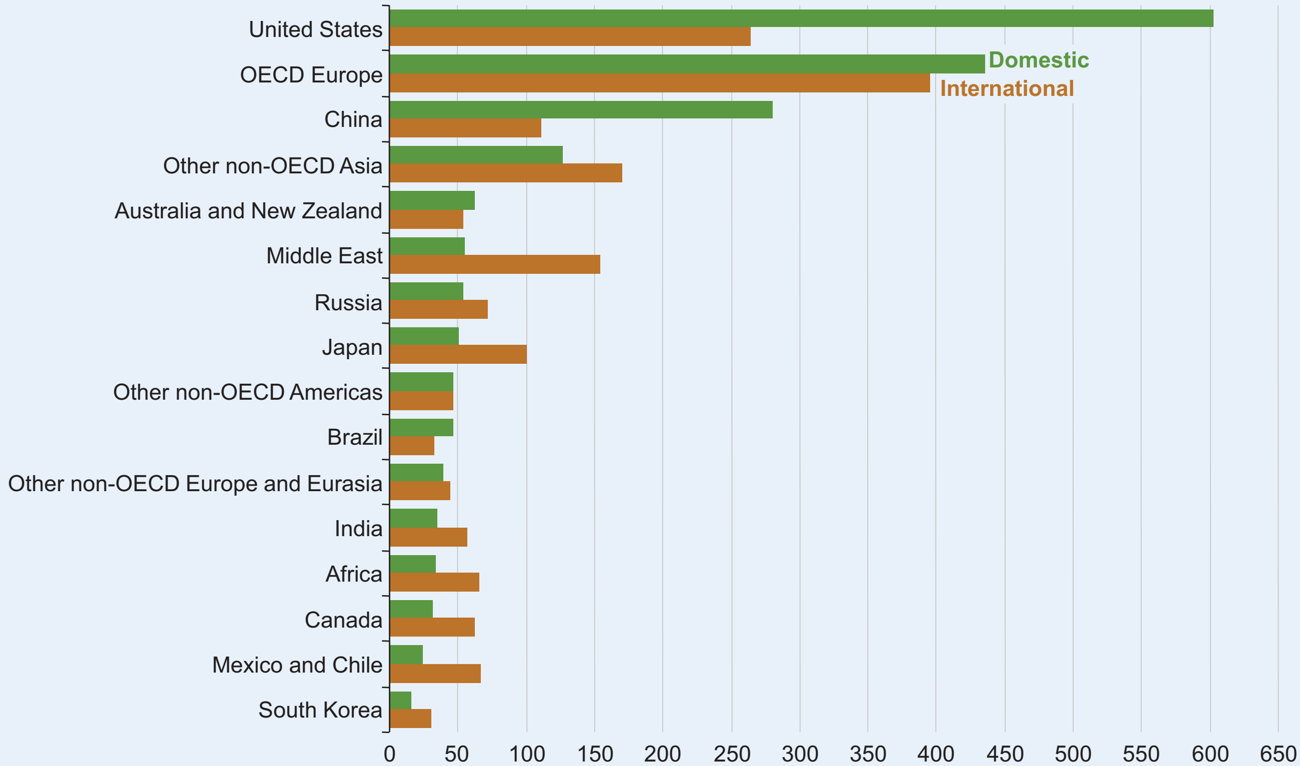
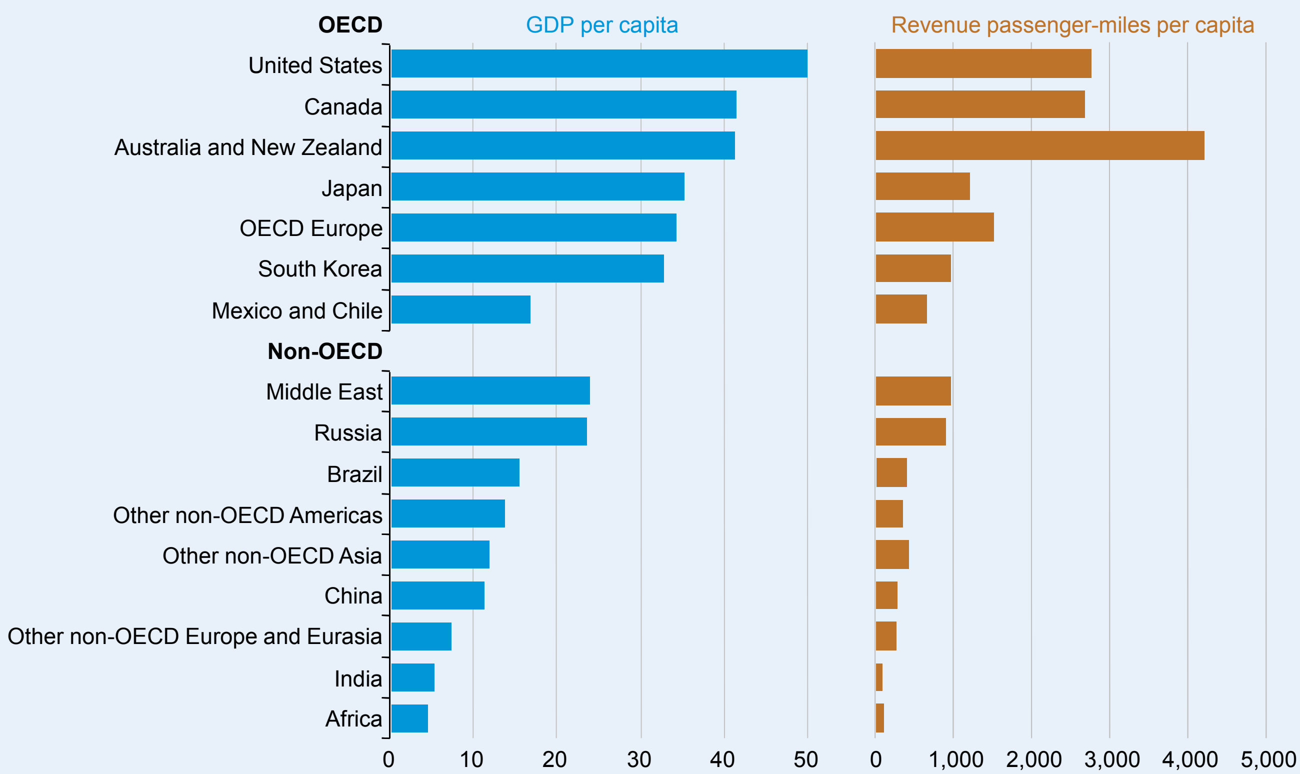


Figure 8-19. OECD and non-OECD gross domestic product per capita (thousand 2010 dollars) and air passenger travel per capita (revenue passenger-miles) by region, 2013



The movement of freight (including trucks, rail, and domestic marine vessels), measured in ton-miles,[328] also shows the impact of economic growth. Freight travel demand is related explicitly to economic activity, including the production and consumption of goods in either intermediate or final form. Non-service industrial gross output[329] per capita and GDP per capita can be used as proxies for production and intermediate and personal consumption. As these two measures increase, the number of freight ton-miles per capita increases. For example, in the IEO2016 Reference case, OECD nonservice industrial gross output per capita increases from about $24,000/person in 2012 to $37,000/person in 2040 (Figure 8-20), and ton-miles per capita increases from about 6.0 thousand ton-miles/person in 2012 to 9.0 thousand ton-miles/person in 2040 (Figure 8-21). Similarly, non-OECD non-service industrial output per capita grows from $10,000/person to $22,000/person, and ton-miles per capita increases from about 2.0 thousand ton-miles in 2012 to 4.0 thousand ton-miles in 2040.

Another source of freight energy consumption is international marine vessels. Worldwide economic growth from the production and consumption of goods, as well as consumption of energy commodities, leads directly to growth in worldwide volumes of maritime freight movement. Approximately 80% of the world's merchandise trade by volume is carried over water, with maritime trade in 2012 totaling nearly 60 trillion ton-miles.[330] Because of globalized supply chains, maritime shipments of nonenergy commodities, such as manufactured goods, agricultural products, and minerals, have grown much faster than global GDP and accounted for approximately 60% of total maritime freight movement in in 2012. Significant amounts of energy commodities, such as crude oil from the Middle East and coal from Australia, also are transported internationally by cargo ships.

Figure 8-20. OECD and non-OECD industrial gross output per capita, excluding service industries, 2012–40 (thousand 2010 dollars)

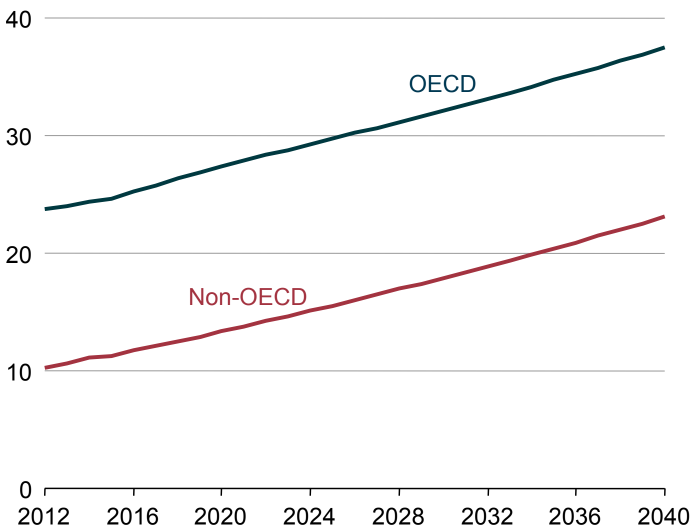
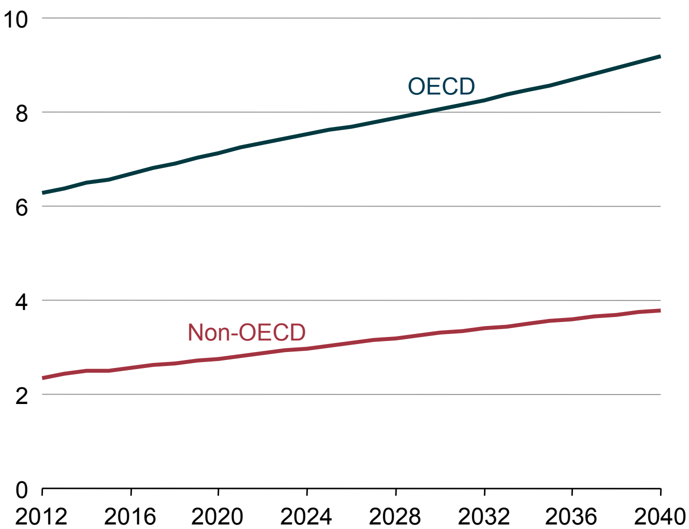


Figure 8-21. OECD and non-OECD freight movement per capita by truck, rail, and domestic marine vessels, 2010–40 (thousand ton-miles)



[328]Ton-mile is a common measure of freight movement, defined as the product of tons and miles, taking into account both distance moved and weight. For example, 100 ton-miles may be 1 ton of freight moved 100 miles or 100 tons of freight moved 1 mile.

[329]The nonservice industrial sector includes agriculture, construction, mining, and manufacturing.

[330]United Nations, Development Policy and Analysis Division, *World Economic Situation and Prospects 2012,* Chapter 2 (New York, NY: 2012), p. 44, http://www.un.org/en/development/desa/policy/wesp/wesp_archive/2012chap2.pdf.