

KEY ISSUE 3

Why Are Energy Resources Important for Development?

Learning Outcome 9.3.1

Explain the principal sources of demand for fossil fuels.

- Energy Supply and Demand
- Alternative Energy Sources

Development is based on availability of abundant low-cost energy. Developed countries use large quantities of energy to produce food, run factories, keep homes comfortable, and transport people and goods. Developing countries expect to use more energy to improve the lives of their citizens.

In Chapter 1, we distinguished between renewable resources (those produced in nature more rapidly than consumed by humans) and nonrenewable resources (those produced in nature more slowly than consumed by humans). Most of the energy resources used by humans are nonrenewable. In the long run, sustainable development will necessitate increased reliance on renewable energy.

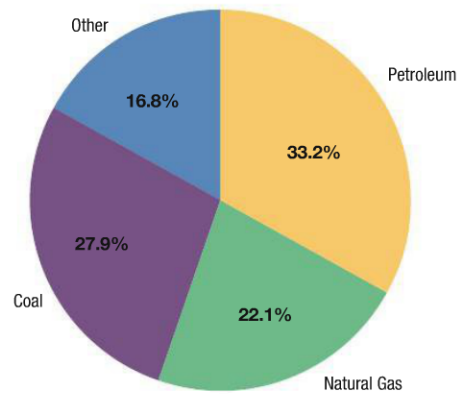
Energy Demand and Supply

Supply is the quantity of something that producers have available for sale. **Demand** is the quantity that consumers are willing and able to buy. Five-sixths of the world's energy needs are supplied by three of Earth's substances (Figure 9-25):

- **Coal.** Coal supplanted wood as the leading energy source in North America and Europe in the late 1800s, as these regions developed rapidly.
- **Petroleum.** Petroleum was first pumped in 1859 but did not become an important source of energy until the diffusion of motor vehicles in the twentieth century.
- **Natural gas.** Natural gas was originally burned off as a waste product of petroleum drilling, but it is now used to heat homes and to produce electricity.

In a developed country like the United States, dependency on these three sources of energy increased rapidly during the twentieth century (Figure 9-26).

Petroleum, natural gas, and coal are known as fossil fuels. A **fossil fuel** is an energy source formed from the residue of plants and animals buried millions of years ago. As sediment accumulated over these remains, intense pressure



▲ FIGURE 9-25 WORLD ENERGY DEMAND Petroleum, coal, and natural gas account for most of the world's energy consumption.

and chemical reactions slowly converted them into the fossil fuels that are currently used. When these substances are burned, energy that was stored in plants and animals millions of years ago is released.

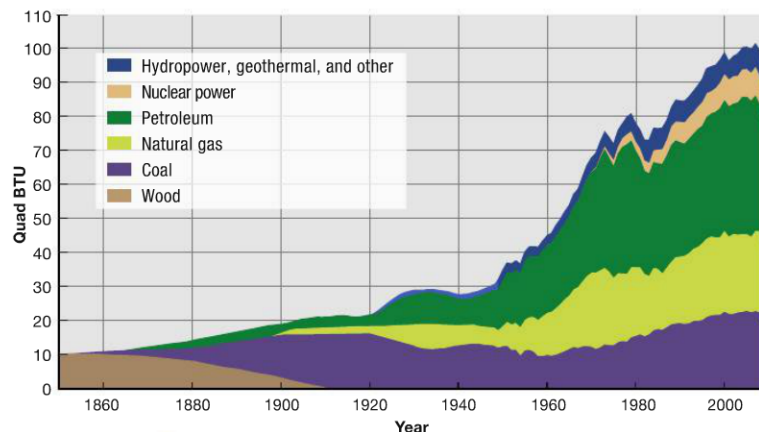
Geographers observe two important inequalities in the global distribution of fossil fuels:

- **Demand.** The heaviest consumers of fossil fuel are in developed countries, whereas most of the reserves are in developing countries.
- **Supply.** Some developing regions have abundant reserves, whereas others have little.

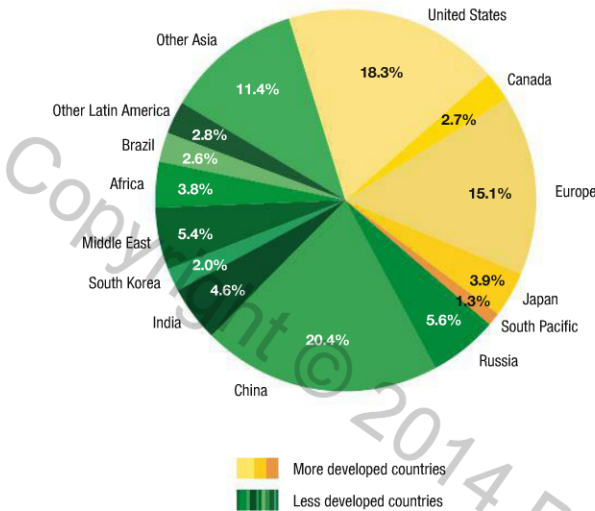
Given the centrality of fossil fuels in contemporary economy and culture, unequal consumption and reserves of fossil fuels have been major sources of instability between developed and developing countries.

Pause and Reflect 9.3.1

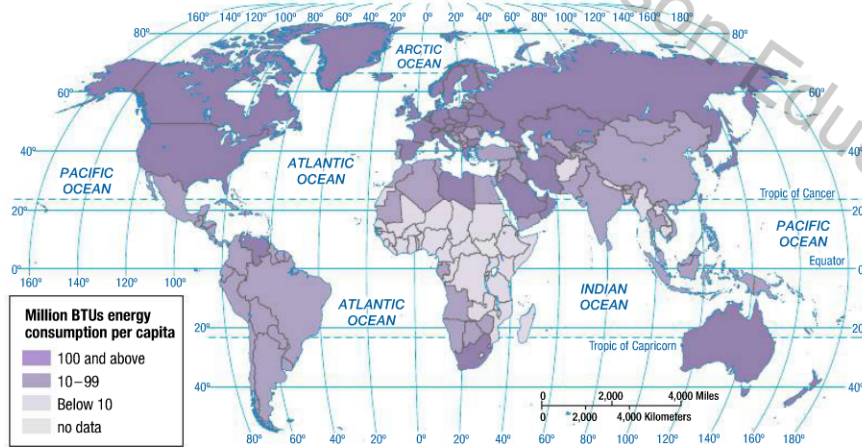
Which energy source increased most rapidly in the United States during the twentieth century?



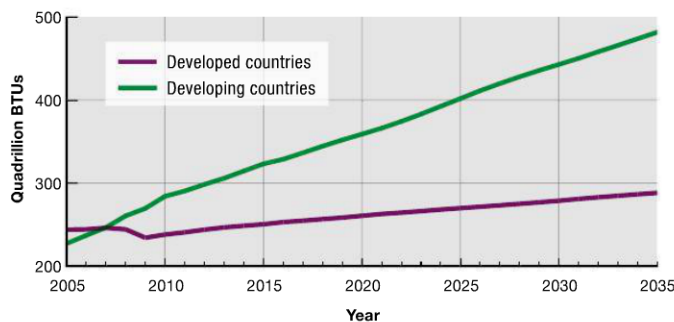
▲ FIGURE 9-26 CHANGING U.S. ENERGY DEMAND Coal was the principal energy source in the nineteenth century. Petroleum and natural gas became important in the twentieth century.



▲ FIGURE 9-27 SHARE OF WORLD ENERGY DEMAND Developed and developing countries each consume around one-half of the world's energy.



▲ FIGURE 9-28 ENERGY DEMAND PER CAPITA The highest per capita consumption is in North America, and the lowest is in sub-Saharan Africa.



▲ FIGURE 9-29 FUTURE ENERGY DEMAND Developing countries are expected to consume 62 percent of the world's energy in 2035.

DEMAND FOR ENERGY

Around one-half of the world's energy is consumed in developed countries and one-half in developing countries (Figure 9-27). The United States had long been the leading consumer of energy, but China now consumes 20 percent of the world's energy, followed by the United States, at 18 percent. The highest per capita consumption of energy is in North America; the region contains one-twentieth of the world's people but consumes one-fourth of the world's energy (Figure 9-28). Developed countries contain only around one-third of the population of developing countries, so per capita consumption of energy is thus around three times higher in developed countries than in developing countries.

Demand for energy comes from three principal types of consumption in the United States:

- **Businesses.** The main energy demand is for coal, followed by natural gas and petroleum. Some businesses directly burn coal in their own furnaces. Others rely on electricity, mostly generated at coal-burning power plants.

- **Homes.** Energy is demanded primarily for the heating of living spaces and water. Natural gas is the most common source, followed by petroleum (heating oil and kerosene).

- **Transportation.** Almost all transportation systems demand petroleum products, including cars, trucks, buses, airplanes, and most railroads. Only subways, streetcars, and some trains run on coal-generated electricity.

In 2007, demand for fossil fuel consumption in developing countries surpassed that of developed countries for the first time (Figure 9-29). The gap in demand between developing and developed countries is expected to widen considerably in the years ahead because consumption of fossil fuels has been increasing at a much faster rate in developing countries—around 3 percent per year, compared to 1 percent per year in developed countries. Increasing reliance on fossil fuels also undermines the goals of sustainable development.

ENERGY SUPPLY

Learning Outcome 9.3.2

Describe the distribution of production of the three fossil fuels.

Energy is required for development, but Earth's energy resources are not distributed evenly. Why do some regions have an abundant supply of reserves of one or more fossil fuels, but other regions have little? This partly reflects how fossil fuels form:

- Coal.** Coal formed in tropical locations, in lush, swampy areas rich in plants. Thanks to the slow movement of Earth's drifting continents, the tropical swamps of 250 million years ago have relocated to the mid-latitudes. As a result, today's main reserves of coal are in mid-latitude countries rather than in the tropics. China is responsible for supplying nearly one-half of the world's coal, other developing countries one-fourth, and developed countries (primarily the United States) the remaining one-fourth (Figure 9-30).
- Petroleum.** Petroleum formed millions of years ago from residue deposited on the seafloor. Some still lies beneath such seas as the Persian Gulf and the North Sea, but other reserves are located beneath land that was under water millions of years ago. Russia and Saudi Arabia together supply one-fourth of the world's petroleum, other developing countries (primarily in Southwest and Central Asia) one-half, and developed countries (primarily the United States) the remaining one-fourth (Figure 9-31).
- Natural gas.** Natural gas, like petroleum, formed millions of years ago from sediment deposited on the seafloor. One-third of natural gas production is supplied by Russia and Southwest Asia, one-third by other developing regions, and one-third by developed countries (primarily the United States) (Figure 9-32). Within the United States, the principal natural gas fields are in Texas, Oklahoma, and the Appalachian Mountains (Figure 9-33).

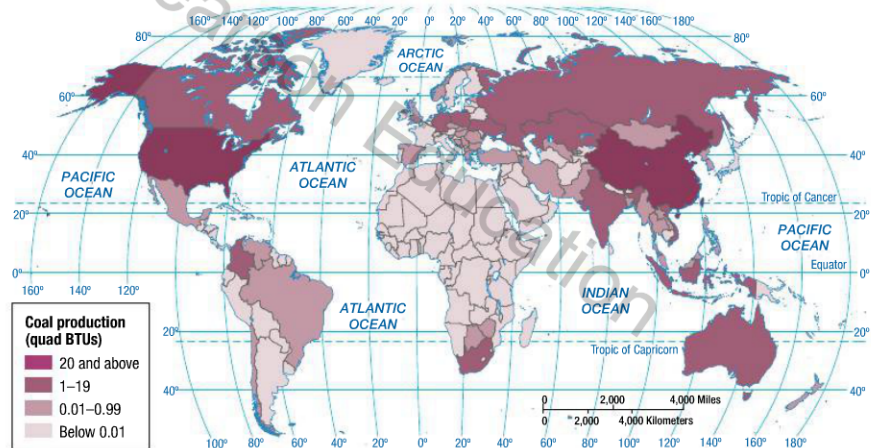
Figures 9-30, 9-31, and 9-32 use the same units (quad BTU), as

well as the same classes. "Quad" is short for quadrillion (1 quadrillion = 1,000,000,000,000,000), and BTU is short for British thermal unit. One quad BTU equals approximately 8 million U.S. gallons of gasoline, which would fill the tanks of one-half million cars.

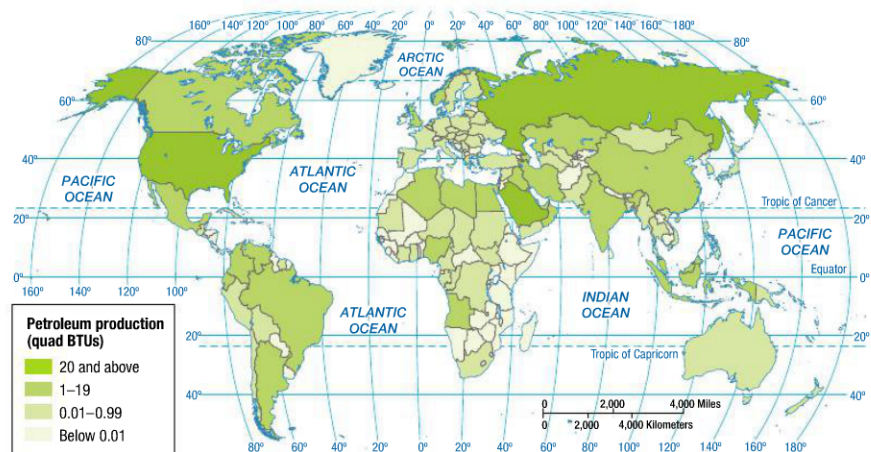
Pause and Reflect 9.3.2

Which country produces at least 20 quad BTUs of all three of the fossil fuels?

Developed countries supply a large share of the world's fossil fuels, but they demand more energy than they produce, so they must import fossil fuels, especially petroleum, from developing countries. The United States and Europe import more than half their petroleum, and Japan imports more than 90 percent. With demand increasing rapidly in developing countries, the developed countries face greater competition in obtaining the world's remaining supplies of fossil fuels. Many of the developing countries with low



▲ FIGURE 9-30 COAL PRODUCTION China is the world's leading producer of coal, followed by the United States.



▲ FIGURE 9-31 PETROLEUM PRODUCTION Russia, Saudi Arabia, and the United States are the leading producers of petroleum.

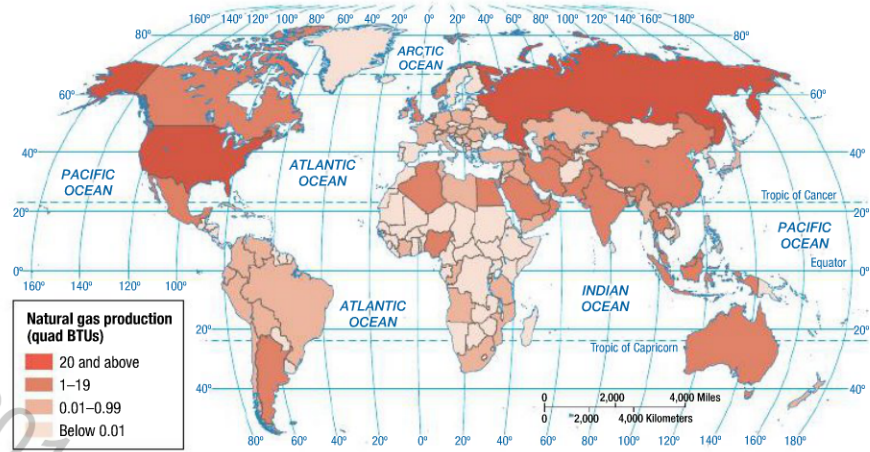
HDI's also lack energy resources, and they lack the funds to pay for importing them.

Compounding future energy challenges, Earth's energy resources are divided between those that are renewable and those that are not:

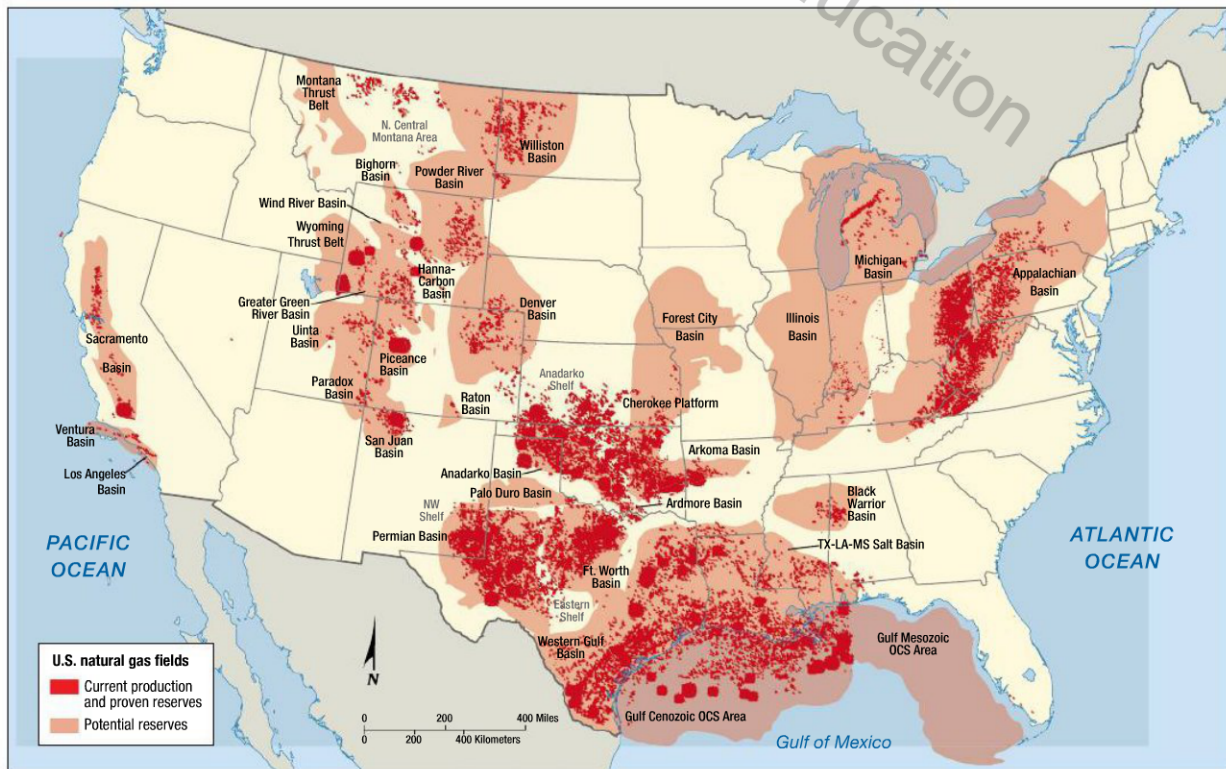
- **Renewable energy** has an essentially unlimited supply and is not depleted when used by people. Examples include hydroelectric, geothermal, fusion, wind, biomass, and solar energy.
- **Nonrenewable energy** forms so slowly that for practical purposes, it cannot be renewed. Examples are the three fossil fuels that currently supply most of the world's energy needs.

Because of dwindling supplies of fossil fuels, most of the buildings in which people live, work, and study will have to be heated another way. Cars, trucks, and buses will have to operate on some other energy source. Because plastic is made from petroleum, objects made of plastic will have

to be made from other materials. Other resources can be used for heat, fuel, and manufacturing, but they are likely to be more expensive and less convenient to use than fossil fuels. And converting from fossil fuels will likely disrupt daily lives and cause hardship. On the other hand, the search for alternatives to fossil fuels may also create development opportunities.



▲ **FIGURE 9-32 NATURAL GAS PRODUCTION** The United States and Russia are the leading producers of natural gas.



▲ **FIGURE 9-33 NATURAL GAS FIELDS IN THE UNITED STATES** The principal natural gas fields are in Oklahoma, Texas, and the Appalachians.

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ENERGY RESERVES

Learning Outcome 9.3.3

Analyze the distribution of reserves of fossil fuels and differentiate between proven and potential reserves.

The world faces an energy challenge because of rapid depletion of the remaining supply of the three fossil fuels that current meet most of the world's energy needs. How much fossil fuel remains? Despite the critical importance of this question for the future, no one can answer it precisely. Because petroleum, natural gas, and coal are deposited beneath Earth's surface, considerable technology and skill are required to locate these substances and estimate their volume.

PROVEN RESERVES. The supply of energy remaining in deposits that have been discovered is called a **proven reserve**. Proven reserves can be measured with reasonable accuracy:

- **Coal.** World reserves are approximately 1 quadrillion metric tons (23 million quad BTUs). At current demand, proven coal reserves would last 131 years. Developed and developing regions each have about one-half of the supply of proven reserves. The United States has approximately one-fourth of the proven reserves, and other developed countries have one-fourth. Most of the developing regions' coal reserves are in Russia and China (Figure 9-34).
- **Natural gas.** World reserves are approximately 175 trillion cubic meters (6,000 quad BTUs). At current demand, proven natural gas reserves would last 49 years.

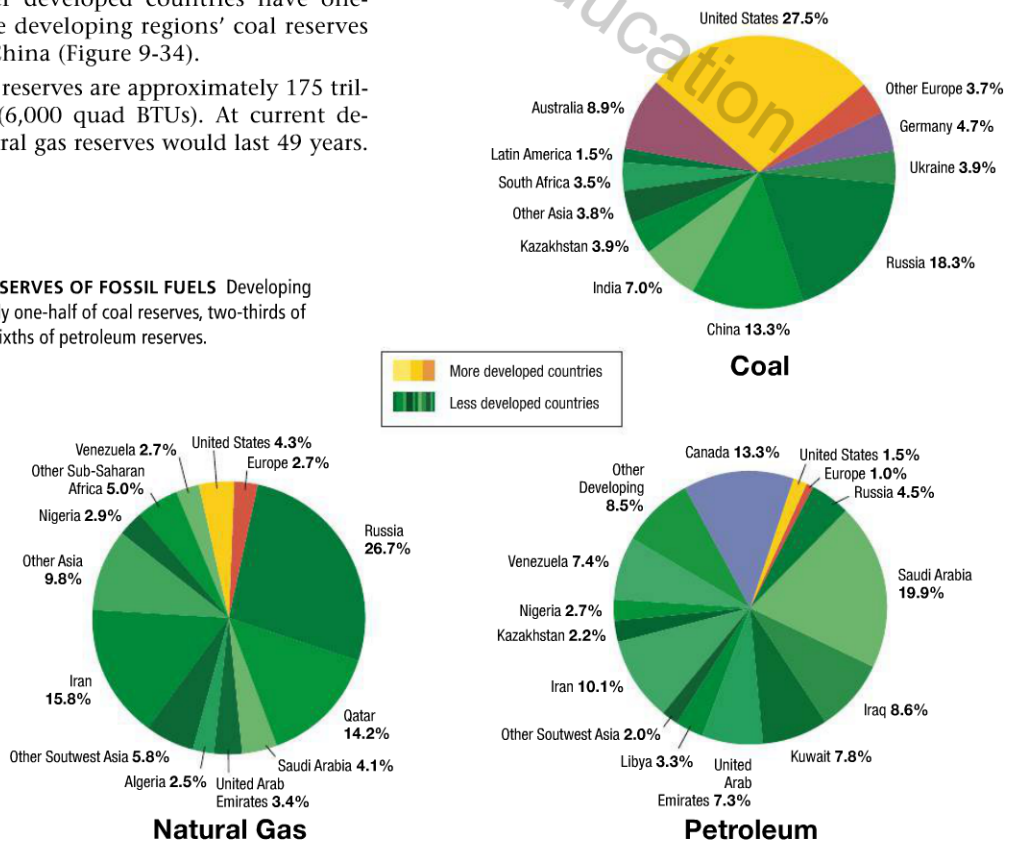
Less than 10 percent of natural gas reserves are in developed countries, primarily the United States. The dark red areas in Figure 9-33 show proven reserve fields in the United States, as well as areas of current production. Russia, Iran, and Qatar together have nearly 60 percent of the world's proven natural gas reserves, and five other developing countries have most of the remainder.

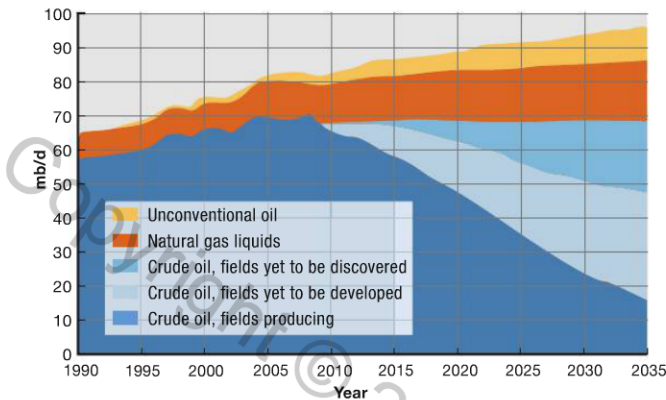
- **Petroleum.** World reserves are approximately 1.3 trillion barrels (5,000 quad BTUs). At current demand, proven petroleum reserves would last 43 years. Developing countries possess 85 percent of the proven petroleum reserves, most of which is in Southwest Asia and North Africa and Central Asia. Saudi Arabia, Canada, and Iran together have more than 40 percent of the world's proven petroleum reserves.

Developed countries have historically possessed a disproportionately high supply of the world's proven fossil-fuel reserves. Europe's nineteenth-century industrial development depended on its abundant coal fields, and extensive coal and petroleum supplies helped the United States become the leading industrial power of the twentieth century.

But this dominance is ending in the twenty-first century. Many of Europe's coal mines have closed because either the coal has been exhausted or extracting the remaining supply would be too expensive, and the region's

▼ **FIGURE 9-34 PROVEN RESERVES OF FOSSIL FUELS** Developing countries possess approximately one-half of coal reserves, two-thirds of natural gas reserves, and five-sixths of petroleum reserves.





▲ **FIGURE 9-35 PETROLEUM PRODUCTION OUTLOOK** The International Energy Agency forecasts that potential reserves will be converted to proven reserves through discovery and development of new fields at about the same rate as already proven reserves are depleted.

petroleum and natural gas (in the North Sea) account for only small percentages of worldwide supplies. Japan has never had significant fossil fuel reserves. The United States still has extensive coal reserves, but its petroleum and natural gas reserves are being depleted rapidly.

Pause and Reflect 9.3.3

No country ranks among the leaders in proven reserves in all three fossil fuels. Which two countries possess at least 10 percent of the proven reserves of two of the three fossil fuels?

POTENTIAL RESERVES. Some fossil fuel deposits have not yet been discovered. The supply in deposits that are undiscovered but thought to exist is a **potential reserve**. When a potential reserve is actually discovered, it is reclassified as a proven reserve (Figure 9-35). Potential reserves can be converted to proven reserves in several ways:

- **Undiscovered fields.** The largest, most accessible deposits of petroleum, natural gas, and coal have already been exploited. Newly discovered reserves are generally smaller and more remote, such as beneath the seafloor, and extraction is costly. Exploration costs have increased because methods are more elaborate and the probability of finding new reserves is less. But as energy prices climb, exploration costs may be justified.
- **Enhanced recovery from already discovered fields.** When it was first exploited, petroleum “gushed” from wells drilled into rock layers saturated with it. Coal was quarried in open pits. But now extraction is more difficult. Sometimes pumping is not sufficient to remove petroleum, but water or carbon dioxide may be forced into wells to push out the remaining resource. The problem of removing the last supplies from a proven field is comparable to wringing out a soaked towel. It is easy to quickly remove the main volume of water, but the last

few percent require more time and patience and special technology.

- **Unconventional sources.** Some sources are called unconventional because methods currently used to extract resources won’t work. Also, we do not currently have economically feasible, environmentally sound technology with which to extract these sources.

An important example of an unconventional source is oil sands, which are saturated with a thick petroleum commonly called tar because of its dark color and strong odor. Native Americans used the tar to caulk canoes in the eighteenth century. The oil must be extracted from the sands through mining, which can be environmentally damaging, and current technology makes processing expensive. Abundant oil sands are found in Alberta, Canada, as well as in Venezuela and Russia. As demand has increased for petroleum, and as prices have risen, the mining of Alberta oil sands has become profitable, and extensive deposits of oil in Alberta oil sands have been reclassified from potential to proven reserves in recent years (Figure 9-36). As a result, Canada is now thought to have 13 percent of world’s petroleum proven reserves, second behind Saudi Arabia, although overall oil sands are still classified as unconventional sources.

Another important unconventional source that has been increasingly exploited in recent years is extraction of natural gas through hydraulic fracturing, commonly called **fracking**. Rocks break apart naturally, and gas can fill the space between the rocks. Fracking involves pumping water at high pressure to further break apart rocks and thereby release more gas that can be extracted. Opponents of fracking fear environmental damage from pumping high-pressure water beneath Earth’s surface. Safety precautions can minimize the environmental threat, but fracking does require the use of a large supply of water, and water is in high demand for other important uses, such as human consumption and agriculture.



▲ **FIGURE 9-36 CANADA’S OIL SANDS** Canada has the world’s second-largest proven reserves of petroleum, which must be extracted from oil sands in Alberta.

CONTROLLING PETROLEUM RESERVES

Learning Outcome 9.3.4

Describe the role of OPEC and changes in the price and availability of petroleum.

Developed countries import most of their petroleum from Southwest Asia & North Africa and Central Asia, where most of the world's proven reserves are concentrated. These regions are the center of ethnic and political conflicts, as discussed in Chapters 7 and 8.

OPEC. Several developing countries possessing substantial petroleum reserves created the Organization of the Petroleum Exporting Countries (OPEC) in 1960. Arab OPEC members in Southwest Asia & North Africa include Algeria, Iraq, Kuwait, Libya, Qatar, Saudi Arabia, and the United Arab Emirates. OPEC members in other regions include Angola, Ecuador, Iran, Nigeria, and Venezuela.

OPEC was originally formed to enable oil-rich developing countries to gain more control over their resource. U.S. and European transnational companies, which had originally explored and exploited the oil fields, were selling the petroleum at low prices to consumers in developed countries and keeping most of the profits. Countries possessing the oil reserves nationalized or more tightly controlled the fields, and prices were set by governments rather than by petroleum companies. Under OPEC control, world oil prices have increased sharply on several occasions, especially during the 1970s and 1980s and in the early twenty-first century (Figure 9-37).

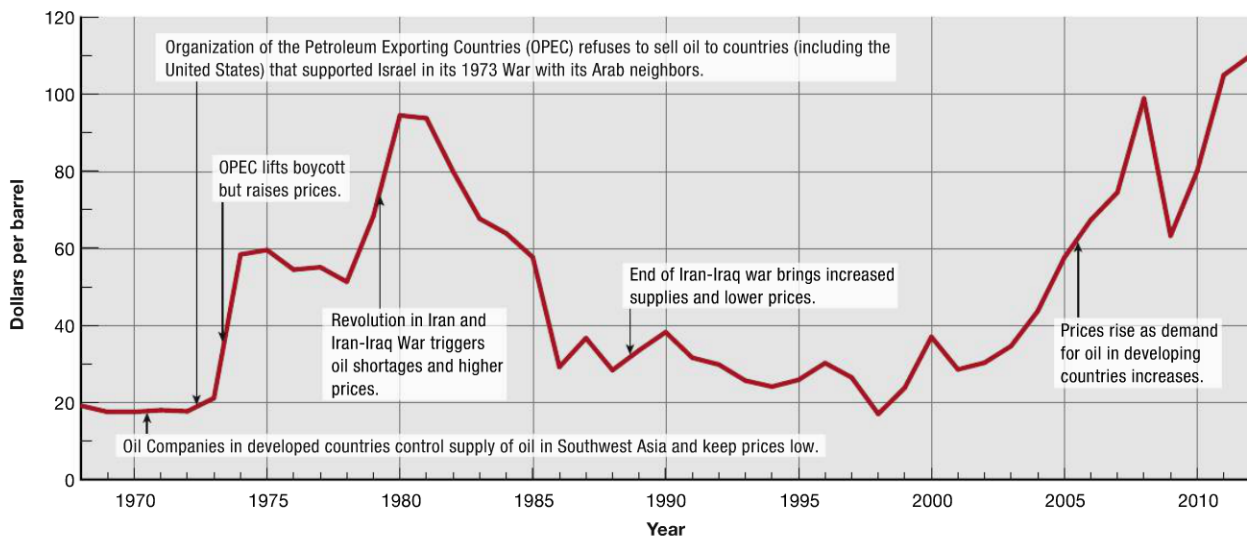
CHANGING U.S. PETROLEUM SOURCES. The United States produced more petroleum than it consumed during

the first half of the twentieth century. Beginning in the 1950s, the handful of large transnational companies then in control of international petroleum distribution determined that extracting domestic petroleum was more expensive than importing it from Southwest and Central Asia. U.S. petroleum imports increased from 14 percent of total consumption in 1954 to 58 percent in 2009 (Figure 9-38). European countries and Japan have always depended on foreign petroleum because of limited domestic supplies. China changed from a net exporter to an importer of petroleum during the 1990s.

The United States reduced its dependency on imported oil in the immediate wake of the 1970s shocks, and the share of imports from OPEC countries declined from two-thirds during the 1970s to one-third during the 1980s (Figure 9-39). Conservation measures also dampened demand for petroleum in most developed countries during the late twentieth century. The average vehicle driven in the United States, for example, got 14 miles per gallon in 1975, compared to 22 miles per gallon in 1985.

The price of petroleum plummeted during the 1980s and settled during the 1990s at the lowest level in modern history, adjusting for inflation (Figure 9-40). With petroleum prices remaining low into the twenty-first century, consumption increased. Americans bought more gas-guzzling trucks and sport-utility vehicles and drove longer distances. Developed countries entered the twenty-first century optimistic that oil prices would remain low for some time. But in 2008, prices hit a record high, in both real terms and accounting for inflation. The 2008 oil shock contributed to the severe global recession that began then.

The world will not literally “run out” of petroleum during the twenty-first century. However, at some point, extracting the remaining petroleum reserves will prove so expensive and environmentally damaging that use of



▲ **FIGURE 9-37 OIL PRICE HISTORY** Oil prices have increased sharply on several occasions.

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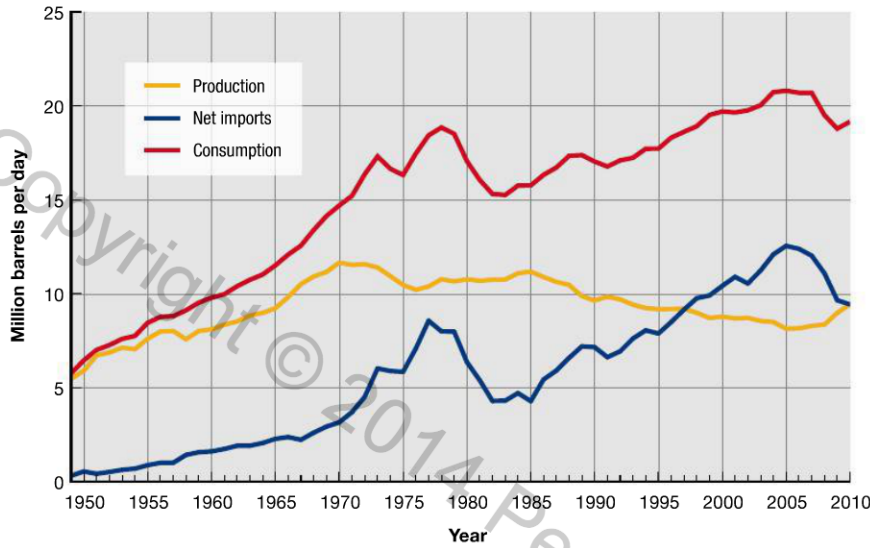


FIGURE 9-38 U.S. PETROLEUM CONSUMPTION, PRODUCTION, AND IMPORTS U.S. production has remained relatively constant since the 1960s. Increasing consumption has been served by increasing imports.

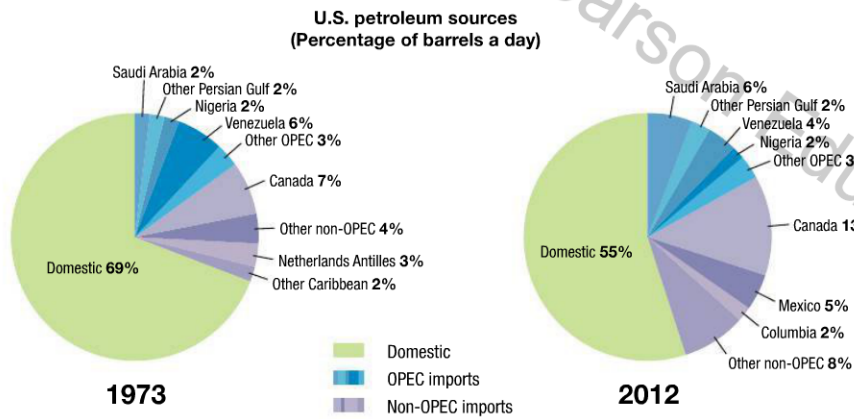


FIGURE 9-39 U.S. PETROLEUM SOURCES The United States imports a higher percentage of petroleum now than in the 1970s. The increase has come primarily from elsewhere in the Western Hemisphere.

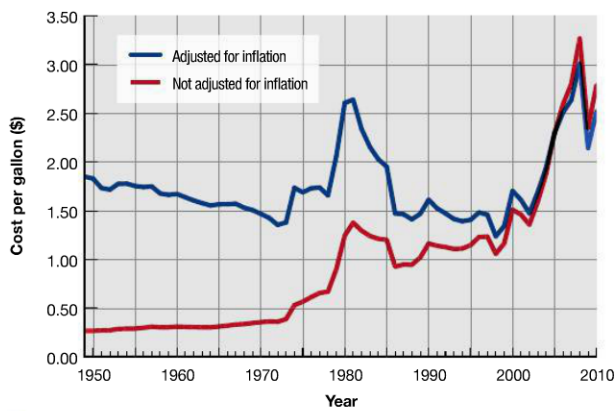


FIGURE 9-40 U.S. GASOLINE PRICES The line adjusted for inflation is in 2005 dollars.

alternative energy sources will accelerate, and dependency on petroleum will diminish. The issues for the world are whether dwindling petroleum reserves are handled wisely and other energy sources are substituted peacefully. Given the massive growth in petroleum consumption expected in developing countries such as China and India, the United States and other developed countries may have little influence over when prices rise and supplies decline. In this challenging environment, all countries will need to pursue sustainable development strategies based on increased reliance on renewable energy sources.

Pause and Reflect 9.3.4
What country exports the most petroleum to the United States?

Alternative Energy Sources

Learning Outcome 9.3.5

Describe the distribution of nuclear energy and challenges in using it.

An especially strong challenge in the quest for sustainable development is substituting renewable energy resources for nonrenewable ones. Although renewable resources can be harnessed for energy, continued reliance on the three main nonrenewable fossil fuels—petroleum, natural gas, and coal—continues to be the less

expensive alternative. About 20 percent of energy consumed in the world, and 15 percent in the United States, is generated by sources other than the three main fossil fuels.

The two principal sources other than fossil fuels are nuclear and hydroelectric energy. But both of these widely used energy sources have limitations when viewed from a sustainable development perspective.

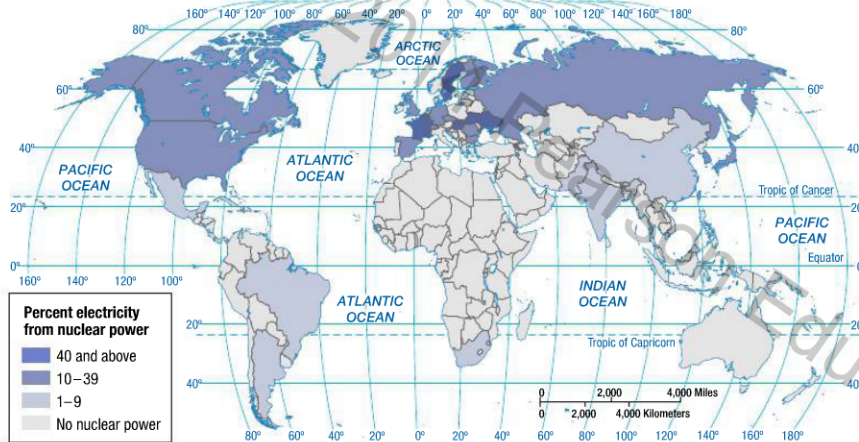
NUCLEAR ENERGY

Nuclear power is not renewable, but some view it as an alternative to fossil fuels. The big advantage of nuclear power is the large amount of energy released from a small amount of material. One kilogram of enriched nuclear fuel contains more than 2 million times the energy in 1 kilogram of coal.

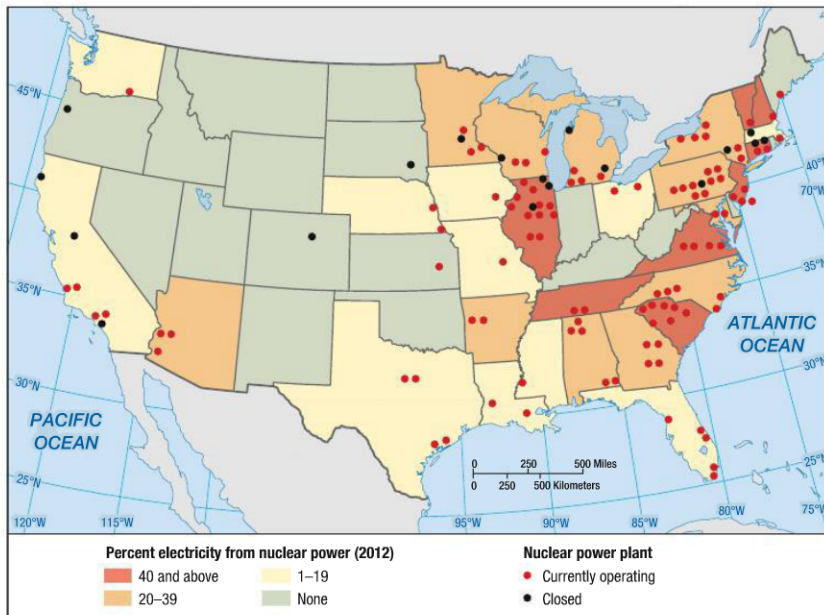
Nuclear power supplies 14 percent of the world's electricity. Two-thirds of the world's nuclear power is generated in developed countries, with Europe and North America responsible for generating one-third each. Only 30 of the world's nearly 200 countries make some use of nuclear power, including 19 developed countries and only 11 developing countries. The countries most highly dependent on nuclear power are clustered in Europe (Figure 9-41), where it supplies 80 percent of all electricity in France and more than 50 percent in Belgium, Slovakia, and Ukraine.

Dependency on nuclear power varies widely among U.S. states (Figure 9-42). Nuclear power accounts for more than 70 percent of electricity in Vermont and more than one-half in Connecticut, New Jersey, and South Carolina. At the other extreme, 20 states and the District of Columbia have no nuclear power plants. Nuclear power presents serious challenges, as described in the following sections.

POTENTIAL ACCIDENTS. A nuclear power plant produces electricity from energy released by splitting uranium atoms in a controlled environment, a process called **fission**. One product of all nuclear reactions is **radioactive waste**, certain types of which are lethal to people exposed to it. Elaborate safety precautions are taken to prevent the leaking of nuclear fuel from a power plant.



▲ FIGURE 9-41 ELECTRICITY FROM NUCLEAR POWER Nuclear power is used in 37 countries, primarily in Europe and North America.



▲ FIGURE 9-42 NUCLEAR POWER BY U.S. STATE One-third of electricity is generated from nuclear power in the Northeast compared to less than one-tenth in the West.

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Nuclear power plants cannot explode, like a nuclear bomb, because the quantities of uranium are too small and cannot be brought together fast enough. However, it is possible to have a runaway reaction, which overheats the reactor, causing a meltdown, possible steam explosions, and scattering of radioactive material into the atmosphere. This happened in 1986 at Chernobyl, then in the Soviet Union and now in the north of Ukraine, near the Belarus border. The accident caused 56 deaths due to exposure to high radiation doses and an estimated 4,000 cancer-related deaths to people who lived near the plant.

Following an earthquake and tsunami in 2011, three of the six reactors at Japan's Fukushima Daiichi nuclear power plant experienced full meltdown, resulting in release of radioactive materials. Three workers died; the death toll among nearby residents exposed to high levels of radioactivity won't be known for years.

RADIOACTIVE WASTE. The waste from nuclear fission is highly radioactive and lethal, and it remains so for many years. Plutonium for making nuclear weapons can be harvested from this waste. Pipes, concrete, and water near the fissioning fuel also become "hot" with radioactivity. No one has yet devised permanent storage for radioactive waste. The waste cannot be burned or chemically treated, and it must be isolated for several thousand years until it loses its radioactivity. Spent fuel in the United States is stored "temporarily" in cooling tanks at nuclear power plants, but these tanks are nearly full. The United States is Earth's third-largest country in land area, yet it has failed to find a suitable underground storage site because of worry about groundwater contamination. In 2002, the U.S. Department of Energy approved a plan to store the waste in Nevada's Yucca Mountains. But soon after taking office in 2009, the Obama administration reversed the decision and halted construction on the nearly complete repository.

BOMB MATERIAL. Nuclear power has been used in warfare twice, in August 1945, when the United States dropped

atomic bombs on Hiroshima and Nagasaki, Japan, ending World War II. No government has dared to use these bombs in a war since then because leaders recognize that a full-scale nuclear conflict could terminate human civilization.

The United States and Russia (previously the Soviet Union) each have several thousand nuclear weapons. China, France, and the United Kingdom have several hundred nuclear weapons each, India and Pakistan several dozen each, and North Korea a handful. Israel is suspected of possessing nuclear weapons but has not admitted to it, and Iran has been developing the capability. Other countries have initiated nuclear programs over the years but have not advanced to the weapons stage. The diffusion of nuclear programs to countries sympathetic to terrorists has been particularly worrying to the rest of the world and has been a major factor in long-time tensions between Iran and other countries that do not want Iran to gain the capability of building a nuclear weapon.

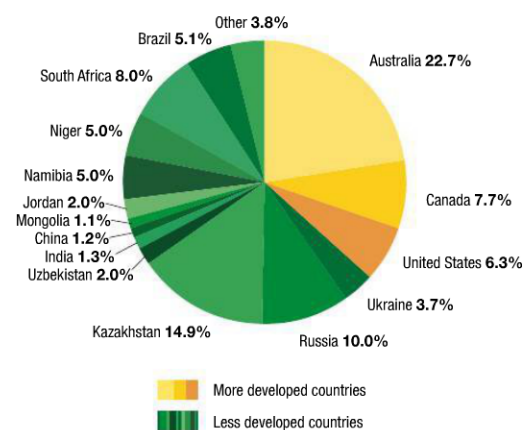
Pause and Reflect 9.3.5

Iran has claimed that it is interested in nuclear power for peaceful uses. Review the maps and charts of fossil fuel production and proven reserves on the previous two spreads. Does Iran appear to have other resources for generating electricity?

LIMITED URANIUM RESERVES. Like fossil fuels, uranium is a nonrenewable resource. Proven uranium reserves will last about 124 years at current rates of use. And they are not distributed uniformly around the world: Australia has 23 percent of the world's proven uranium reserves, Kazakhstan 15 percent, and Russia 10 percent (Figure 9-43). The chemical composition of natural uranium further aggravates the scarcity problem. Uranium ore naturally contains only 0.7 percent U-235; a greater concentration is needed for power generation.

A **breeder reactor** turns uranium into a renewable resource by generating plutonium, also a nuclear fuel. However, plutonium is more lethal than uranium and could cause more deaths and injuries in an accident. It is also easier to fashion into a bomb. Because of these risks, few breeder reactors have been built, and none are in the United States.

HIGH COST. Nuclear power plants cost several billion dollars to build, primarily because of the elaborate safety measures required. Without double and triple backup systems at nuclear power plants, nuclear energy would be too dangerous to use. Uranium is mined in one place, refined in another, and used in still another. As with coal, mining uranium can pollute land and water and damage miners' health. The complexities of safe transportation add to the cost. As a result, generating electricity from nuclear plants is much more expensive than from coal-burning plants. The future of nuclear power has been seriously hurt by the high costs associated with reducing risks.



▲ FIGURE 9-43 WORLD URANIUM RESERVES

Australia, Kazakhstan, and Russia have the most uranium reserves, 2014 from 205.215. The high cost of uranium is a major barrier to its use in nuclear power. Use of this information without a valid subscription date represents a copyright violation.