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# Energy Security in the United States

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Note: Numbers in the text and tables may not add up to totals because of rounding.

## Summary

Energy use is pervasive throughout the U.S. economy. Households and businesses use energy from oil, natural gas, coal, nuclear power, and renewable sources (such as wind and the sun) to generate electricity, provide transportation, and heat and cool buildings. In 2010, energy consumption represented 8.4 percent of U.S. gross domestic product.

Disruptions in the supply of commodities used to produce energy tend to raise energy prices, imposing an increased burden on U.S. households and businesses. Disruptions can also reduce the nation's economic output and thus people's income. This paper examines energy security in the United States—that is, the ability of U.S. households and businesses to accommodate disruptions of supply in energy markets—and actions that the government could take to reduce the effects of such disruptions.

The vulnerability of the U.S. economy to disruptions in the supply of a particular energy source depends on the importance of that energy source to the economy. More than 80 percent of the energy consumed in the United States comes from oil, natural gas, or coal. For each source, several factors determine how vulnerable the nation is to a disruption in its supply:

- The extent to which disruptions occurring anywhere in the world affect energy costs in the United States,
- The likelihood of disruptions and the ability of energy suppliers to respond to disruptions if they occur, and
- The ability of energy consumers (including electricity producers, oil refiners, households, and businesses) to shift to other, less expensive sources of energy.

Consumers and the economy are more vulnerable to disruptions in oil markets than they are to disruptions in other energy markets, as shown by a comparison of the two largest energy-consuming sectors of the U.S. economy—transportation and electricity. In particular, transportation is almost exclusively dependent on oil supplied in a global market in which disruptions can cause large price changes. Moreover, consumers have few easy and inexpensive options for switching to other fuels or reducing consumption of transportation fuels. In contrast, electricity can be produced from several sources of energy, all of which are less prone to disruptions, and consumers have more options for reducing demand for electricity.

## The Potential for Global Disruptions to Affect U.S. Energy Prices

Disruptions in the supply of any commodity tend to raise that commodity's price; however, disruptions in the supply of oil have a much larger effect on prices than interruptions in the supply of other energy commodities. The extensive network of pipelines, shipping, and other options for transporting oil around the world means that a single world price for oil prevails, after accounting for the quality of that oil and the cost of transporting it to the marketplace. Except for countries where the price of oil is regulated or subsidized in certain ways, disruptions related to oil production that occur anywhere in the world raise the price of oil for every consumer of oil, regardless of the amount of oil imported or exported by that consumer's country. In contrast, the high cost of moving natural gas, coal, nuclear power, and renewable energy limits their markets to geographically bounded regions, such as North America. Consequently, foreign disruptions have had little or no effect on the prices of those fuels in the United States.

Although the global nature of the market for oil makes U.S. consumers vulnerable to price fluctuations caused by events elsewhere in the world, it also benefits those consumers by lowering the price of oil relative to what it would be in a regional oil market; that benefit would be greater, however, if the global market was less prone to disruptions or if oil producers and consumers were better able to adjust to such disruptions.

## The Likelihood of Disruptions and the Ability of Suppliers to Adjust to Them

A substantial amount of oil is produced in countries that are vulnerable to disruptions resulting from geopolitical, military, or civil developments, and few countries other than Saudi Arabia have much spare production capacity in the near term to offset such disruptions. In contrast, the U.S. markets for natural gas, coal, nuclear power, and renewable energy either are less prone to long-term disruptions or have significant spare production and storage capacity. For example, U.S. producers and consumers of natural gas maintain a significant reserve in storage (30 percent of annual consumption in 2010). Similarly, stocks of coal in 2010 represented 9 weeks of U.S. consumption and, over the past decade, producers of coal in the United States maintained an average spare production capacity of 17 percent. Much of the limited potential for disruptions in the supply of those fuels involves their transport across the United States (via pipeline, railcar, river barge, or truck), for which redundancy and spare transport capacity exist.

## The Ability of Energy Consumers to Adjust to Disruptions

The U.S. electricity system is quite flexible and operates with significant spare capacity in most circumstances. That spare capacity means that when western coal is not available to electricity providers in the East, for example, they can shift generation to facilities that rely on coal from Illinois or Appalachia or increase generation from natural gas or renewable sources. In addition, some facilities are maintained in reserve and operated only during periods of peak electricity demand or during a disruption at another facility. Thus, when the price of one commodity used to generate electricity rises, another commodity can be substituted, keeping electricity prices relatively stable.

In contrast, the United States has no alternatives that can be readily substituted in large quantities for oil in providing fuel for transportation. Moreover, consumers have less flexibility in the near term in how they use transportation, and changes in transportation use tend to be more expensive over the long term than changes in electricity use. For example, households and businesses can reduce electricity consumption by adjusting their thermostat settings or switching to energy-efficient light bulbs in the near term, or they can switch to natural gas heating or energy-efficient appliances over the long term. However, most decisions that would reduce transportation costs, such as what vehicle to drive or where to live, cannot easily be altered in the near term. Changes can be made over the long term, but such adjustments tend to be more expensive than those that can be made to reduce electricity use.

## Policy Options to Improve Energy Security in Transportation

Addressing concerns about U.S. energy security requires considering policies related to the nation's supply of and demand for oil, because transportation relies so heavily on that commodity. Because of the global nature of the oil market, no policy could eliminate the costs borne by consumers as a result of disruptions but some policies could reduce those costs. This report examines the ability of some commonly proposed policies to decrease those costs, but it does not evaluate the costs or benefits of implementing those policies or how well they would address other objectives.

Policies designed to address temporary disruptions could seek to increase the supply of oil (by releasing oil from the Strategic Petroleum Reserve, for instance); facilitate development of markets to provide insurance that would protect consumers against sharp increases in prices; or provide consumers with options for reducing their consumption of oil (by expanding public transportation service, for example, or promoting the use of telecommuting). A release of oil from the Strategic Petroleum Reserve or more widespread use of insurance could reduce the impact of some disruptions, although the beneficial effects of such policies could be neutralized if releases were not implemented in coordination with other oil-producing countries or the insurance did not transfer risk to those better able to bear it. Policies that enabled consumers to use their vehicles less during periods of high gasoline prices would be more likely to lower costs for households and businesses.

Policies designed to decrease the impact of increases in oil prices that persist for several years or more can also be divided into those that would increase the supply of oil or oil substitutes (such as increasing domestic oil production) and those that would encourage consumers to reduce their reliance on oil (such as increasing the gasoline tax or developing vehicles that are more fuel efficient or that use other types of fuel). Both types of policies would tend to lower the world price of oil, either by making more oil available to the world market or by reducing demand for it. However, the effect of either type of policy on the world price would probably be small. Many analysts (including the U.S. Energy Information Administration) expect that large oil-producing countries would reduce their actual or planned production of oil in the face of increased production of oil in the United States, thereby diminishing or eliminating the effect of such U.S. actions on the world price of oil. Recently, for instance, Saudi Arabia announced that it would reduce its planned expansion of oil production in light of increased production in Brazil and Iraq.

Policies that promoted greater production of oil in the United States would probably not protect U.S. consumers from sudden worldwide increases in oil prices stemming from supply disruptions elsewhere in the world, even if increased production lowered the world price of oil on an ongoing basis. In fact, such lower prices would encourage greater use of oil, thus making consumers more vulnerable to increases in oil prices. Even if the United States increased production and became a net exporter of oil, U.S. consumers would still be exposed to gasoline prices that rose and fell in response to disruptions around the world.

When a disruption occurs, those countries with spare production capacity—of which Saudi Arabia is the largest—can determine whether to partially or fully offset the disruption. In fact, Saudi Arabia has chosen to offset, to a large extent, the impact of disruptions by increasing production when oil prices rise because of a disruption. If the United States was able to develop similar spare production capacity held in reserve until disruptions occurred, that capacity could be used to limit increases in oil prices during times of disruption—but pursuing that option would probably be costly or impractical. Production capacity in the United States is owned by private firms and operated on the basis of the geologic characteristics of the oil reserves and the returns required by shareholders. Without sufficient compensation, private firms would be unlikely to hold newly developed capacity in reserve and use it only to offset disruptions in other countries. Therefore, such spare capacity would probably need to be owned by the U.S. government.

In contrast, policies that reduced the use of oil and its products would create an incentive for consumers to use less oil or make decisions that reduced their exposure to higher oil prices in the future, such as purchasing more fuel-efficient vehicles or living closer to work. Such policies would impose costs on vehicle users (in the case of fuel taxes or fuel-efficiency requirements) or taxpayers (in the case of subsidies for alternative fuels or for new vehicle technologies). But the resulting decisions would make consumers less vulnerable to increases in oil prices.

## Energy Security and Its Economic Significance

Energy plays a vital role in Americans' lives and in the U.S. economy as a whole, particularly in the provision of electricity, transportation, heating and cooling, and industrial processing—the four main energy-consuming sectors of the economy. Energy consumption in those four sectors equaled 8.4 percent of gross domestic product (GDP) in 2010 (see Table 1).

This report examines the various commodities used to generate energy in the United States, focusing on the two largest energy-consuming sectors of the U.S. economy—electricity and transportation—and the differences in how they expose U.S. households and businesses to disruptions, either domestic or international, in the supply of energy. In particular, electricity is generated from multiple sources (coal, natural gas, nuclear power, and renewable fuels) that are primarily supplied in regional markets made up of one or more countries; in contrast, the transportation sector in the United States is powered almost exclusively by oil, which is supplied in a global market (see Figure 1).

## What Is Energy Security?

One widely used definition of energy security—and the one used in this report—is the ability of U.S. households and businesses to accommodate disruptions of supply in energy markets.[1] Following a disruption or threat of disruption, energy prices can rise, imposing costs on U.S. consumers. Households and businesses are "energy secure" with respect to a particular source of energy if a disruption in the supply of that source would create only limited additional costs.

At times, policymakers have defined energy security in other ways. Some policymakers, for example, define energy security as having the flexibility to choose not to import oil from countries associated with terrorism or from countries that might seek to use their exports of oil to influence international affairs. That definition is often accompanied by a desire to rely on energy products from domestic sources or from countries that are unlikely to change the terms of their exports to the United States on the basis of its foreign policy decisions. Although there might be some benefits from increased domestic production, those benefits probably would not stem from an improvement in energy security as defined in this report. That is the case because competition within the marketplace ensures that all countries receive the same price for their energy products, after accounting for quality and transportation costs. Thus, even if the United States produced all of the oil it consumes (as Canada does), the nation would still be vulnerable to disruptions that cause oil prices to increase. Moreover, reducing imports of oil or other energy products from a particular country would probably not affect the income received by that country as long as other countries were willing to purchase those products. In global or regional markets, the price of energy depends on total consumption by all consumers within the same global or regional market.

1. That definition conforms with those used by, for example, World Economic Forum, "The New Energy Security Paradigm," *Energy Vision Update* (Spring 2006); Michael Toman, "The Economics of Energy Security: Theory, Evidence, Policy," in A.V. Kneese and J.L. Sweeney, eds., *Handbook of Natural Resource and Energy Economics,* vol. 3 (Amsterdam: Elsevier B.V./North Holland, 1993); and Lutz Kilian, "The Economic Effects of Energy Price Shocks," *Journal of Economic Literature,* vol. 46, no. 4 (December 2008), pp. 871–909.

## Economic Effects of Disruptions in the Supply of Energy

Disruptions in the supply of energy impose both direct costs and indirect costs on households and businesses faced with higher energy prices. When supply disruptions cause energy prices to rise, U.S. households and businesses incur *direct costs* by paying more for goods and services (such as electricity, gasoline, and heat) produced by that energy. The magnitude of those costs—whether incurred on a temporary or persistent basis—hinges, in part, on the options available for consumers to lower their expenditures on energy. In the near term, consumers can respond to higher energy prices in a number of ways—for example, by changing the temperature on their thermostat, switching to energy-efficient light bulbs, driving less or more slowly, or vacationing away from home less frequently. Those responses limit the cost increases that consumers face. Over the long term, consumers have more options for reducing their exposure to disruptions in energy markets because they have more time to budget for and make energy-saving decisions. For example, they can decide where to live or locate a business, what type of vehicle or fleet to purchase, and whether to buy heating and air conditioning units that are more energy-efficient. The more near-term and long-term alternatives consumers have available for responding to disruptions in energy markets, the less exposure they have to those disruptions.

The direct costs—greater spending on some goods and services—would cause U.S. households and businesses to reduce their consumption of other goods and services, particularly if there were limited near-term alternatives for consumers to use less energy. That reallocation of resources among sectors and to energy producers would impose *indirect costs* on the economy that many economists consider to be the primary channel through which disruptions in energy supply affect the economy.[2] In particular, aggregate demand would be diminished in the near term for a number of reasons. Higher energy prices would shift income and wealth within the United States to energy producers and owners of the sources of energy, such as coal mines or oil and natural gas fields. That shift could temporarily reduce the demand for goods and services in the economy. Similarly, if the increase in energy prices stemmed from an increase in the price of crude oil, more money would be paid to foreign producers and owners of oil assets. The increased buying power overseas would not immediately translate into increased demand for U.S. exports. Furthermore, a large and sudden change in the price of an important consumer good—caused, for example, by a disruption in the supply of energy—could have a short-term impact on consumer spending by affecting consumer confidence. People might postpone some purchases out of concern about

2. See Kilian, "The Economic Effects of Energy Price Shocks." For related discussion, see Keith Crane and others, *Imported Oil and U.S. National Security* (Santa Monica, Calif.: RAND Corp., 2009); Lutz Kilian, "Exogenous Oil Supply Shocks: How Big Are They and How Much Do They Matter for the U.S. Economy?" *Review of Economics and Statistics,* vol. 90, no. 2 (May 2008), pp. 216–240; and James D. Hamilton, "Oil and the Macroeconomy," in Steven N. Durlauf and Lawrence E. Blume, eds., *The New Palgrave Dictionary of Economics,* vol. 6 (New York: Palgrave Macmillan, 2008), pp. 172–177.

how the disruption would affect the economy. Those reductions in demand would tend to lead businesses to temporarily reduce investment and employment, thereby diminishing household income and further lowering consumer spending. An increase in crude oil prices would also have a permanent effect on the economy, as the increase in payments to foreign producers and owners of oil assets would represent a transfer of wealth out of the United States.

The ultimate effect on the economy of an increase in energy prices would depend on the response of the Federal Reserve to expected changes in inflation and employment. Under typical economic circumstances, an increase in energy prices that reduced demand would also increase the costs of production, leading to higher inflation. However, if the Federal Reserve raised short-term interest rates to avoid an increase in inflation, it would exacerbate the drop in output and the rise in unemployment.[3]

As one example, a sustained $50 per-barrel rise in oil prices from about $100 (the price in April 2012) would be expected to boost gasoline prices by $1.20, to more than $5.00 per gallon. Consumers would probably reduce the amount of gasoline they used by a small amount; on net, consumers' annual expenditures on gasoline would rise by about $150 billion, and consumption of other goods and services would fall. The Congressional Budget Office (CBO) estimates, on the basis of historical experience, that such an increase in prices would reduce real (inflation-adjusted) GDP over the subsequent four quarters by ½ percent to 1 percent below what it would be if oil prices remained near their current level. At today's oil prices, changes of more or less than that amount would have roughly proportionate effects on the economy; thus, an additional increase of $10 per barrel would reduce GDP by 0.1 percent to 0.2 percent.

By CBO's estimate, the projected overall effect on the economy would differ somewhat from what occurred between the beginning of 2004 and early 2006, when the price of crude oil doubled from $30 to $60 per barrel. In a 2006 report, CBO estimated that the doubling in the price of oil lowered GDP by about 1 percent by the end of that period.[4] With oil prices now at roughly $100 per barrel, expenditures for petroleum products make up a larger share of the economy than they did in early 2004. Consumer outlays for motor vehicle fuels were 1.7 percent of GDP in the fourth quarter of 2003 but 2.6 percent of GDP in the fourth quarter of 2011. Because a $30 increase now would be a smaller percentage increase relative to today's higher prices, such an

3. In the current environment, however, the Federal Reserve has indicated a desire to keep interest rates exceptionally low for an extended period; as a result, it would probably be less inclined to raise short-term interest rates in the face of an increase in energy prices over the next couple of years. That restraint would probably lead to a smaller effect on economic output in the near term from an increase in energy prices, but a larger effect on near-term inflation.

4. See Congressional Budget Office, *The Economic Effects of Recent Increases in Energy Prices* (July 2006).

increase would have a smaller effect on the economy today than it did from 2004 to 2006. But a doubling of oil prices today would have a larger economic effect.

## Potential Effects of Disruptions in Key Energy Markets

A disruption in the market for an energy commodity would probably increase the price of that commodity, but the amount of the increase would depend on the attributes of the market. Disruptions can come from shocks to the supply of energy, such as the hurricanes in the Gulf of Mexico in 2005 or the political unrest that occurred in Libya in 2011. Both events caused the price of oil to increase. (Energy prices can also increase because of significant changes in the demand for energy. For example, the dramatic increase in Chinese demand for energy in the 2000s pushed up the price of energy consumed in many other countries, including the United States.)[5] This report is primarily about disruptions in the supply of energy, but U.S. consumers are vulnerable to disruptions in supply or demand for energy. To the extent that a particular commodity is not part of a global market but is instead traded primarily in regional or local markets, such disruptions may not affect the price of energy paid by U.S. consumers if those disruptions occur in other countries. However, a more localized market will tend to concentrate the economic harm when disruptions occur in that market.

Any disruption has the potential to raise prices unless producers of the affected commodity are able to offset the disruption by quickly boosting their own production or drawing down their own stores of the commodity. The price increase from any such disruption would be similar for all consumers in the same global, regional, or local market as that in which the disruption occurred. Because producers of oil have a limited ability to increase production to offset disruptions and because oil is traded in a global market, disruptions anywhere in the world would be expected to raise oil prices for all consumers. In contrast, producers of coal, natural gas, nuclear power, and renewable energy maintain excess production capacity or storage to offset disruptions. Also, because those commodities are traded in regional or local markets, disruptions outside the United States, Canada, and a few other nearby trading partners would probably not affect their price in the United States.

### Oil

The market for crude oil has the following key characteristics:

- A substantial amount of oil is produced in countries that are vulnerable to geopolitical, military, or civil disruptions;

- Oil is supplied in a global market that rapidly transmits the effect of disruptions to the prices paid in all oil-consuming nations, regardless of the amount of oil those nations produce domestically;

5. See Congressional Budget Office, *China's Growing Demand for Oil and Its Impact on U.S. Petroleum Markets* (April 2006).

- Most oil-producing countries have a limited spare capacity to increase production over the short term in response to such disruptions; and

- The United States has very little ability to affect the world price of oil by increasing the supply of oil to the market.

Compounding the above effects, consumers of oil products (such as gasoline) have very few options for reducing consumption or switching to other fuels when disruptions occur (see pages 23–24 for more information about the consumption of oil).

**Risks of Disruptions.** Disruptions in the production of oil are most likely to occur because of instability in oil-producing countries.[6] More than 100 countries produce oil, but a much smaller group produces a large share of the world's oil (see Table 2): In 2010, the 12 countries that constitute the Organization of Petroleum Exporting Countries (OPEC) supplied 43 percent of the world's oil; Russia, the United States, and China accounted for another 26 percent.

OPEC was created by a desire of the organizing countries to collectively determine production amounts to keep oil prices within a target band. In addition to possible disruptions in individual oil-producing countries, disruptions in supply could also occur if OPEC members coordinated to reduce their production.[7] The production decisions by most OPEC members are made by the government (whereas in the United States, private firms set production amounts). Because, collectively, OPEC is the largest producer of oil in the world, a decision by that organization to reduce production could have repercussions throughout the world.

Significant production outages or threats of such outages anywhere in the world are likely to increase oil prices for all consumers; for example, oil prices increased significantly around the world following the Arab oil embargo in 1973; the Iranian revolution in 1979; the Persian Gulf conflict in 1990; Venezuelan civil unrest in 2002; Gulf of Mexico hurricanes Dennis, Katrina, and Rita in 2005; and the Libyan uprising in 2011. The extent of such increases depends on the ability of consumers to substitute other fuels for oil, although there is limited potential for such substitutions in the short term.

**A Global Market.** A defining characteristic of the oil market is its global nature: The network of shipping, pipeline, and transport options that moves oil around the world means that oil from anywhere in the world is generally bought and sold at a single price (though the price may vary depending on the quality of the oil and the costs of transporting it to the market). Consequently, disruptions in the supply of oil anywhere in

6. The instability of oil-producing countries is described in more detail in Gail Cohen, Frederick Joutz, and Prakash Loungani, "Measuring Energy Security: Trends in the Diversification of Oil and Natural Gas Supplies," *Energy Policy,* vol. 39, no. 9 (September 2011), pp. 4860–4869.

7. For example, in the 1970s some oil-exporting countries in the Middle East reduced their production of oil in response to U.S. foreign policy actions in the region.

the world rapidly result in higher oil prices worldwide. For example, disruptions in Iran—a country from which it is illegal for U.S. companies to import oil—that were not offset by increased production elsewhere would increase the price of every barrel of oil consumed in the United States, including the 39 percent produced domestically (as of 2011). A change in the price of any country's oil that is not caused by changes in its quality will be accompanied by a similar change in the price of every other country's oil (see the leftmost graph in Figure 2).[8]

Such changes in global oil prices translate directly into price changes for the products made from refining crude oil, such as gasoline.[9] As a result, gasoline prices tend to rise and fall at the same time everywhere in the world. That outcome can be seen in the path of gasoline prices between 1999 and 2011 in Japan, Canada, and the United States (see Figure 3). Although gasoline prices in the three countries differed because of fees and taxes in each country, the changes in prices were consistent across countries. That result holds true even though over the time period evaluated, Japan produced almost no oil, the United States produced 30 percent to 40 percent of the oil it used each year, and Canada was a net exporter of oil. Thus, even if the United States increased production to become a net exporter of crude oil, U.S. consumers would still be exposed to gasoline prices that rose and fell in response to disruptions around the world.

The global nature of the oil market comes with benefits and costs for U.S. consumers. The global market benefits U.S. consumers by giving them access to less expensive oil; a market limited to North America or just the United States would have far higher oil prices because the demand for oil in the United States exceeds the supply from U.S. or North American producers. The United States currently imports 61 percent of the oil it consumes.[10] More than 50 percent of the imported oil comes from Canada, Mexico,

8. Crude oil is a mixture of hundreds of different chemicals. Its quality varies by region of the world, among other factors. Higher-quality crude oil contains less water, sulfur, and organic matter (such as dirt) and more of the components that are easier to burn (like propane and butane).

9. Some countries impose controls on gasoline prices. As a result, consumers may not pay the full cost of gasoline, and gasoline prices do not fluctuate with the world market. For example, Iran has historically offered heavily subsidized gasoline to its citizens; in December 2010, however, some of those subsidies were removed, and gasoline prices in that country nearly quadrupled.

10. In 2011, the United States imported only 45 percent of the liquid components required to make petroleum products, of which oil is the largest; that percentage is smaller than the 61 percent mentioned above because it includes other fuel additives and processes that increase the total volume of oil when it is converted to petroleum products. Thus, the United States would need to increase oil production by almost 160 percent in order to produce enough oil domestically to meet its demand for petroleum products. For more information, see Department of Energy, Energy Information Administration, *This Week in Petroleum* (May 25, 2011).

and other non-OPEC members; the remainder is imported from OPEC members.[11] Another benefit of a global market is that it spreads domestic disruptions in supply over a larger market, which reduces any resulting increase in U.S. prices when a disruption in U.S. production occurs. But one cost of such a global market is that U.S. consumers are affected by supply shocks that occur anywhere in the world. That drawback is significant in the case of oil, because oil is produced by many countries that, relative to the United States, are less stable and more susceptible to shocks.

Attempts to isolate the United States from the global market for oil would almost certainly fail, because demand for oil in the United States exceeds domestic supply and because isolation would require a fundamentally different energy market, with restrictions on prices and exports that would probably not be feasible (see Box 1). Unless all imports and exports of oil were banned, any imports of oil from abroad—such as from Canada or Mexico—would still allow the world price to be transmitted through such countries to the United States. The United States' trading partners would choose to sell oil to the United States only when the U.S. price was higher than the world price (causing the U.S. price to fall toward the world price) and deliver it elsewhere when the U.S. price was lower than the world price (causing the U.S. price to rise toward the world price). Without such imports from abroad, demand for oil in the United States could be met only with prices sufficiently high to cause demand to fall to the level of domestic production.

**Response of Other Oil-Producing Countries to Disruptions.** In the near term, only a few countries, of which Saudi Arabia is the most significant, have the ability to increase production to compensate for a supply disruption elsewhere; that ability gives those countries considerable power to determine the extent to which disruptions in oil production affect oil prices. If those countries with spare production capacity do not act to offset disruptions, then even small disruptions can affect the world's supply of oil and ultimately its price.[12] The size of recent disruptions to oil production has ranged from a few hundred thousand barrels a day (as occurred in June 2008, when protestors disrupted production in Nigeria) to more than 1.5 million barrels per day (as occurred when Libya stopped exporting oil in early 2011 because of political unrest).

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11. In 2011, the United States became a net exporter of petroleum products (such as gasoline, diesel, and jet fuel) but continued to be a net importer of crude oil. In that year, the United States had net exports of 3 million barrels of petroleum products and net imports of 459 million barrels of oil. See Department of Energy, Energy Information Administration, "U.S. Imports and Exports" (January 9, 2012).

12. The Energy Information Administration defines spare capacity as the volume of production that can be brought on within 30 days and sustained for at least 90 days. The responsiveness of oil production to changes in the price of oil is measured using the price elasticity of supply. That elasticity is estimated to be 0.02 to 0.04 in the near term and 0.10 to 0.35 over the long run; in other words, a 10 percent increase in price would boost supply by 0.2 percent to 0.4 percent over the near term and by 1.0 percent to 3.5 percent over the long run. See James Smith, "World Oil: Market or Mayhem," *Journal of Economic Perspectives,* vol. 23, no. 3 (Summer 2009), pp.145–164.

The spare production capacity maintained by Saudi Arabia is unique in the market; it averaged 1.9 million barrels per day (ranging from 0.5 to 4.0 million barrels per day) between 2003 and 2011 (see Figure 4). On average over that period, Saudi Arabia accounted for 84 percent of the world's spare capacity. Nearly all of that country's spare capacity is controlled by Saudi Aramco (the government-owned oil company); thus, the Saudi Arabian government can unilaterally decide to increase production to limit the effect on worldwide prices of a disruption elsewhere in the supply of oil, or to allow such a disruption to increase oil prices. In fact, Saudi Arabia tends to adjust its production in the same direction as movements in oil prices. When oil prices rise, Saudi Arabia tends to boost its production, thus preventing prices from rising even further. And as prices fall, Saudi Arabia tends to reduce its production. Although the reasons underlying those decisions to increase or decrease production probably differ at various times, they always greatly influence world oil prices.

Some analysts suggest that OPEC (of which Saudi Arabia is a member) would like to avoid price increases that provide sufficient incentive for consumers to make long-run decisions to reduce their use of oil.[13] If so, OPEC would probably be more likely to intervene to reduce the effect of disruptions that create large increases in oil prices and less likely to implement coordinated action to raise prices when they are already high.

**U.S. Reaction to Disruptions.** Because the United States has no near-term spare production capacity and because it cannot rapidly reduce its consumption of oil products, this country has very few near-term options for responding to disruptions in oil markets. The most significant tool available in the short term is the substantial quantity of oil stored in the United States, particularly in the government's Strategic Petroleum Reserve (SPR); however, the release of that oil has not been used to offset most of the supply disruptions that have occurred in the past. Use of the SPR would have two disadvantages: It could be offset if other oil-producing countries reduced their output, and its ability to lower world oil prices for an extended period would probably be small. (See page 26 for further discussion about the potential use of the SPR.)

Over the long run, the United States could explore for and develop additional oil resources, which would tend to increase the supply of oil. However, development of new oil resources in the United States—particularly oil fields in deep water off the coast—could take more than 10 years. Moreover, the ability of large government-owned oil producers elsewhere to strategically respond to such increased supply means that the ultimate effect of increased U.S. production would probably be dampened. That is, increasing production of oil in the United States might not increase the world's oil supply substantially or lower the price of oil significantly.

13. Neelesh Nerurkar and Mark Jickling, *Oil Price Fluctuations,* CRS Report for Congress R42024 (Congressional Research Service, August 26, 2011).

In addition, because any new productive capacity in the United States would be controlled by private firms and not the government (as it is for OPEC members), that new capacity would be used in amounts determined by its owners and not held as spare capacity to offset disruptions. If the United States was able to develop spare production capacity that could be held in reserve until disruptions occurred, that capacity would provide the country with enhanced ability to avoid sharp increases in oil prices. The feasibility of such a strategy would depend, in large part, on the geologic characteristics of oil fields that might serve as a source of oil reserves; starting and stopping production of oil from U.S. reserves (unlike reserves in Saudi Arabia) can be expensive. Moreover, such spare capacity would probably need to be owned by the U.S. government; private firms would require significant compensation not to produce oil at the rate they determined best maximized returns to their shareholders.

### Natural Gas

Natural gas is widely used as an energy source, primarily to produce electricity and to provide heating and air conditioning. Very little natural gas is used for transportation (it accounts for less than 3 percent of transportation fuels), which means that recent discoveries of natural gas in the United States do not reduce U.S. vulnerability to oil price increases. The market for natural gas, like the market for oil, has limited spare production capacity to offset supply disruptions in the near term. However, several features of the natural gas market differentiate it from the oil market and allow disruptions to have a muted effect on U.S. prices.

Most importantly, U.S. producers and consumers of natural gas maintain a significant reserve of natural gas in storage (30 percent of annual domestic consumption in 2010), which is drawn down or added to fairly regularly; in contrast, oil storage in the United States represents a much smaller supply of annual world consumption (less than 4 percent in 2010).[14] That storage provides firms that use natural gas a significant cushion against temporary disruptions in supply. In addition, in some parts of the United States, more natural gas is produced than can be sold profitably, causing producers to dispose of the excess.[15] A persistent disruption that put upward pressure on natural gas prices could create sufficient incentives for firms to build additional infrastructure to enable them to sell their excess natural gas.

Another key factor is the high cost of transporting natural gas across oceans (where pipelines are not practical). As a result, natural gas is primarily consumed by the country producing it or traded within a regional market (for example, North America or

14. Just as with oil, some of the natural gas in storage is kept as permanent inventory to maintain pressure in pipelines and underground reservoirs. Every year, about half of that stored reserve is used and subsequently replaced; most of the withdrawals occur during the winter months, when demand for natural gas (which is used for heating) is highest.

15. For example, see Department of Energy, Energy Information Administration, "Over One-Third of Natural Gas Produced in North Dakota Is Flared or Otherwise Not Marketed," *Today in Energy* (November 23, 2011).

Russia/Europe).[16] Thus, only disruptions within a particular region will affect natural gas prices within that region. For example, disruptions in natural gas supplies in Russia or Indonesia would not appreciably affect natural gas prices in the United States (see the middle graph in Figure 2), but they would affect prices in Europe and Japan, respectively.[17] In 2010, the United States produced 89 percent of its natural gas domestically and imported the rest (primarily from Canada, Egypt, and Trinidad and Tobago).

Within each regional market, natural gas is transported in one of two ways:

- It is moved using pipelines between two geographic areas that are physically close, such as Canada or Mexico and the United States, or

- It is liquefied (converted temporarily to liquid form for ease of transport or storage) and then shipped via rail, truck, or tanker.

Disruptions in the supply of natural gas within the United States and among its trading partners tend to involve pipeline maintenance or leaks and thus to be smaller than disruptions in the supply of oil. The geographic diversity of natural gas production and the redundancy of pipelines cause such disruptions to have a limited effect on natural gas prices within the United States. Natural gas was produced in more than 30 states in 2010, from either onshore or offshore sources, and significant pipeline capacity exists to transport that gas within various regions of the country. However, because limited pipeline capacity exists in the United States to move natural gas between the West and the East, pipeline disruptions can affect prices in certain parts of the country. For example, disruptions associated with Hurricane Katrina near the Gulf of Mexico in 2005 increased natural gas costs in the East (which is dependent on gas from the Gulf) but not in the West (which receives gas from elsewhere).[18] Persistent disruptions, such as would occur if a large natural gas field ceased operation, would increase natural gas prices until new supplies were developed within the United States or by its natural gas trading partners.

Neither temporary nor persistent disruptions in the market for liquefied natural gas would be likely to affect natural gas prices in the United States. That is because lique-

16. Major consumer markets are North America, Europe, and Asia (primarily China and Japan), and major sources of production are the United States, Russia, South Africa, Indonesia, and Australia. Natural gas in the United States is sold at market prices based on supply and demand conditions; outside the United States, however, most natural gas (for example, from Russia, Norway, and Australia) is sold at a price indexed to the price of oil. Although such indexing (meaning that natural gas prices rise and fall with oil prices) adds transparency to a market that otherwise lacks competition, it also tends to keep natural gas prices high in those areas.

17. However, sometimes global events, such as the 2008 world recession, can cause natural gas prices worldwide to move in similar directions.

18. See Energy and Environmental Analysis, *Hurricane Damage to Natural Gas Infrastructure and Its Effect on the U.S. Natural Gas Market* (report prepared for The Energy Foundation, November 2005).

fied natural gas constituted only about 1 percent of the U.S. natural gas supply in 2010. In addition, contracts for liquefied natural gas tend to be long term (typically 20 years), and the price is set as a fixed multiple of the price of oil; thus, changes in natural gas prices would probably not affect contract prices for liquefied natural gas unless oil prices also changed.

The significant new discoveries of natural gas in the United States over the past few years have caused some analysts to suggest that the United States and Canada might increase their capability to export liquefied natural gas to other parts of the world, particularly Europe, where natural gas prices were more than three times U.S. prices in 2011. Such increased export capacity would cause the U.S. regional market for natural gas to become increasingly connected to the European market for natural gas. As a result, natural gas prices in the two regions would probably adjust to a similar level, rising in the United States and falling in Europe, and natural gas disruptions in either location would affect prices in both regions. However, if increased liquefaction capacity was not large enough to cause the two markets to become fully connected, new supplies of natural gas discovered within the U.S. market could offset the natural gas exported abroad, causing natural gas prices in the United States to remain lower than those in Europe.[19]

### Coal

Almost half of the electricity generated in the United States comes from the burning of coal; electricity is produced from coal in every state except Vermont and Rhode Island. Because coal is not used for transportation, increased or decreased production of coal does not affect U.S. vulnerability to disruptions in oil markets.

Coal is expensive to transport abroad, so it is traded primarily within regional markets. In 2010, the United States produced more than 1 billion tons of coal and exported, on net, about 60 million tons, largely to Brazil, Canada, and Europe. Thus, only disruptions within the United States would be likely to affect U.S. coal prices. Foreign disruptions in the supply or production of coal, such as strikes in South Africa or Australia, would have little or no effect on U.S. coal prices (see the rightmost graph in Figure 2).[20]

Within the United States, coal producers store large amounts of coal and have significant spare production capacity. Those two factors make the supply of coal, like the supply of natural gas, more stable than the supply of oil, and limit the likelihood and potential impact of supply disruptions.

19. Recent discoveries of natural gas throughout the world suggest that prices may remain low worldwide, so the development of liquefaction facilities may not be warranted.

20. Global events can cause coal prices to move in similar directions in Russia, South Africa, and the United States; however, regional coal markets tend to be similar to those for natural gas.

Temporary disruptions in the supply of coal affect coal prices within regions of the United States only to the extent that one region of the country depends on coal from the region affected by the disruption and there is no redundancy in the transportation options connecting the regions. In 2010, coal was transported primarily via railroad (70 percent), truck (12 percent), and river barge (11 percent) across the United States from the 25 states where it was produced to those where it is consumed. Localized disruptions at a coal mine, such as a temporary shutdown, are unlikely to affect coal prices because electric power plants that rely on coal often receive it from multiple locations and maintain a multiweek supply onsite. Stocks of coal in 2010 represented 18 percent, or more than 9 weeks, of U.S. consumption, giving coal producers a buffer against the effects of temporary disruptions.

Persistent disruptions could increase coal prices if other U.S. producers did not respond by boosting their production. Between 2003 and 2004, rail congestion reduced the ability to haul coal from the western United States to electricity producers in the East, which increased the price of coal in the East but lowered it in the West.[21] When disruptions are not caused by transportation problems but by other events, such as an explosion or a large accident at an underground mine, other coal producers can often respond by increasing their production. Over the past decade, producers of coal in the United States maintained an average spare production capacity of 17 percent, meaning that they could expand the number of hours or days they operated to increase production by 17 percent using existing mines, permits, and equipment.[22] If coal prices increased following a large persistent disruption and that spare capacity was exhausted, prices would probably remain elevated until new supplies could be developed or until substitutes for coal (such as natural gas or nuclear power used to generate electricity) caused the demand for coal to decrease.

### Nuclear Power

Nuclear power is used exclusively to generate electricity. In 2010, the United States had 65 working nuclear power plants that operated a total of 104 reactors and generated 21 percent of all electricity. Nuclear facilities are typically always running because they have low operation and maintenance costs (in contrast to their high construction and licensing costs).

Electricity in the United States is primarily traded within multistate regions that surround its area of production. (Some of those regions also include parts of Canada.) For that

21. Western coal, particularly from Wyoming and Colorado, has a lower sulfur content than coal from the eastern United States. Such coal is attractive to operators of electric power plants in eastern and midwestern states, which must comply with requirements under the Acid Rain Program to emit less sulfur dioxide.

22. See Department of Energy, Energy Information Administration, *Annual Coal Report 2009,* DOE/EIA-0584, "Table 12, Capacity Utilization by Coal Mines by State" (2009), as well as the same report and table from earlier years.

reason, the 2011 nuclear outage in Japan and the 1986 Chernobyl disaster in Russia had no effect on U.S. electricity prices, nor would similar events in the future.[23]

If a disruption occurred at a U.S. nuclear power plant, the electricity that was lost would be replaced by power generated from more expensive sources, causing the average cost of electricity to increase. The August 2011 earthquake in the eastern United States caused two nuclear power plants to shut down for several days. High-cost backup generators that operate using different fuels were rapidly activated, and the cost of electricity generation immediately increased by more than 50 percent. Within a few hours, however, other low-cost backup generating units had ramped up, and costs subsequently fell back to near original levels.[24]

If a nuclear accident caused U.S. regulators or the public to question the reliability or safety of many or all U.S. nuclear facilities, then other backup electricity generators could face considerable strain. Such a large disruption affecting the source of 21 percent of the electricity generated in the United States would probably increase the price of other commodities (such as coal) that are used to generate electricity.

### Renewable Sources

Most energy generated in the United States from renewable sources is derived from hydropower, wood, and biofuels (primarily transportation fuels produced mainly from renewable plant matter, but not wood). In 2010, those three sources provided 31 percent, 25 percent, and 23 percent, respectively, of the renewable energy generated in the United States. Other sources of renewable energy are wind power (accounting for 11 percent of the renewable energy generated in 2010), waste (6 percent), geothermal energy (3 percent), and solar power (1 percent). Hydropower and geothermal energy tend to be highly dependable sources of energy and not prone to short-term disruptions; in contrast, wind and solar power are inherently irregular and prone to naturally occurring interruptions.

Disruptions to the supply of renewable energy can come in the form of temporary interruptions (such as periods of no wind or limited sun) or events with long-lasting consequences (such as forest fires or droughts). Some types of disruptions—particularly droughts, which affect hydropower and the growth of organic material for the production of biofuels (for example, corn for ethanol)—can reduce the reliability of renewable

23. The only way such an effect could occur would be through world oil prices, but the United States generates less than 1 percent of its electricity using oil, and worldwide less than 1 percent of electricity was generated using oil in 2008, on average. Moreover, the prevalence of coal and natural gas as sources of electricity around the world combined with the high cost of oil makes it unlikely that any country would substitute oil for nuclear power as a source of electricity. Thus, nuclear outages overseas would be unlikely to affect U.S. electricity prices.

24. See Department of Energy, Energy Information Administration, "Mid-Atlantic electricity market reacts to Tuesday's earthquake," *Today in Energy* (August 25, 2011), www.eia.gov/todayinenergy/detail.cfm?id=2810.

energy over the long term. The frequency of temporary interruptions often requires that other energy sources, such as natural gas, serve as a backup, increasing the cost of renewable energy. As the network of renewable-energy facilities expands and becomes more geographically diversified, however, temporary interruptions in one location could be offset by production from other locations not experiencing an interruption.

## What Role Can the Government Play in Enhancing Energy Security?

Action by the government to reduce the effects of disruptions to energy markets could be warranted both because the direct costs of such disruptions may impose hardships on segments of the population and because the indirect costs affect the nation as a whole. But in the case of a long-term disruption, government actions to ameliorate its impact could interfere with the adjustments consumers would make in response to higher prices.

Government actions might take the form of increasing the ease with which consumers can shift to alternative energy sources following a disruption. Or they might attempt to increase or diversify the domestic supply of energy to reduce the magnitude of disruptions experienced by U.S. consumers. Policies that were designed to increase the cost of energy to reflect all of the costs associated with its production and use, including indirect and environmental costs, would provide an economic incentive to reduce the use of energy and to develop and use alternative technologies. Some such policy options are discussed in more detail in the last section of this report.

Addressing inefficiencies in markets other than energy markets could also make consumers less vulnerable to price disruptions. For example, businesses commonly invest less money than is socially optimal in research and development—in part because they do not take into account the benefits to society from knowledge spillovers that would accrue to other businesses. That lower amount of spending on the development of technology means that consumers have less access to more energy-efficient technologies or alternative forms of energy, for example; thus, they incur higher direct costs from a disruption than would otherwise be the case. Policies that took into account the spillover benefits resulting from research and development on energy alternatives could lead to a better use of resources and could lessen the burden of higher energy prices on U.S. consumers.

Adopting policies that reduced the likelihood of disruptions occurring within energy markets in the United States could also improve energy security. For example, policies might increase safety standards in coal mines or at nuclear power plants, thus reducing the likelihood of disruptions in the production of coal or nuclear energy. Or policies might increase redundancy in electricity transmission lines or pipelines, which would reduce the vulnerability of the infrastructure used to transport electricity and oil to an accidental breakdown or a terrorist attack. Other policies might involve foreign policy actions or investments in military equipment that could help ensure key routes for oil tankers are kept open. Although this report examines the consequences of disruptions that might occur in the production of energy, it does not discuss the underlying probability that those disruptions would occur. Thus, the effect of policies that might lessen that probability is outside the scope of this report.

## Energy Security for Electricity

Although the electricity sector of the U.S. economy consumes more energy than any other sector, households and businesses are largely unaffected by disruptions in the supply of commodities that underlie electricity generation.[25] The effects of such disruptions on the electricity bills of households and businesses are limited by features that distinguish the electricity sector from the next-largest energy-consuming sector, transportation:

- Several different commodities can be consumed in the generation of electricity.
- Generation in the United States is organized into eight multistate regions that are part of the North American Electric Reliability Corporation (NERC); each region is responsible for maintaining sufficient spare capacity to respond to disruptions. That spare capacity offers electricity providers significant flexibility to choose among electricity generating units and fuels.
- Consumers of electricity can often choose among various options to reduce their electricity usage in the near and long terms when price increases occur.

In 2010, almost all electricity in the United States was generated from coal, nuclear power, natural gas, and renewable sources (see Figure 5). By contrast, less than 1 percent of electricity was produced from oil. In general, the markets for commodities that are used to produce electricity are stable and not prone to large or long-lasting disruptions; that stability tends to keep average electricity prices within a much narrower band than gasoline prices (see Figure 6).

### Regional Generation, Spare Capacity, and Flexibility

Domestic disruptions in the supply of the commodities used to produce electricity can have an effect on the price of electricity, but the effect will vary because of the regional nature of electricity generation and the options available for transporting fuels. Electricity generation in the United States is divided into three primary zones, across which there is little trade: the Western Interconnection (considered one region, spanning all or

25. This section focuses on disruptions in the supply of energy commodities and not disruptions to the infrastructure used to distribute electricity to consumers. For more information on the latter, see Richard Campbell, *Regulatory Incentives for Electricity Transmissions—Issues and Cost Concerns,* CRS Report for Congress R42068 (Congressional Research Service, October 28, 2011); John Moteff, *Critical Infrastructures: Background, Policy, and Implementation,* CRS Report for Congress RL30153 (Congressional Research Service, July 11, 2011); and Richard Campbell, *The Smart Grid and Cybersecurity—Regulatory Policy and Issues,* CRS Report for Congress R41886 (Congressional Research Service, June 15, 2011).

part of 13 western states), the Texas Interconnection, and the Eastern Interconnection (see the top panel of Figure 7). The latter encompasses 34 states divided into six regions across and within which electricity is traded. NERC regulates each of the eight regions (under authority granted to it in 2007 by the Federal Energy Regulatory Commission) to ensure that generation capacity is sufficiently large to withstand outages or unplanned disruptions in fuel delivery.

Because each region uses a different combination of fuels to generate electricity and has its own network of rails and pipelines to connect suppliers of energy commodities with electricity providers, disruptions can affect each region differently (see the middle and bottom panels of Figure 7). For example, several regions in the Eastern Interconnection rely more heavily on coal to generate electricity than regions elsewhere in the United States. Thus, coal disruptions affect electricity generation in the East more than in the West. Similarly, although all regions rely on natural gas as a fuel source, there is limited pipeline capacity to move natural gas between the West and the East, so natural gas disruptions typically are isolated to one-half of the country.

Each NERC region has excess capacity designed to respond to temporary disruptions in the fuel sources it uses. In 2009, the eight NERC regions averaged 22 percent excess capacity, measured as the unused available capacity of the region at peak summer load as a percentage of available capacity. That excess capacity totaled 200 gigawatts and ranged from approximately 3 gigawatts to 60 gigawatts in individual regions. (For comparison, the largest providers of electricity generate roughly 1.5 gigawatts, and more than 97 percent of providers deliver less than 0.5 gigawatts at peak summer capacity; thus, 60 gigawatts of spare capacity represents the output of more than 40 individual plants and probably many more.) That spare capacity means that when western coal is not available to electricity providers in the East, they can shift generation to facilities that rely on coal from Illinois or Appalachia or increase generation from natural gas or renewable sources (see Box 2).

In addition to shifting generation between facilities, some producers have the ability to switch the fuels used by particular facilities. So even though coal-burning facilities are typically designed to process a specific type of coal, they can substitute coal from another source, typically up to 20 percent, without incurring additional costs. Some producers also can substitute natural gas for coal within the same facility. As of 2009, about 1 percent of electricity was produced by burning coal and natural gas together; that share could increase if natural gas prices remain low and the cost to retrofit a facility for such switching becomes less expensive than the cost of building a new natural gas facility. Biomass can also be burned with coal (at volumes of up to 10 percent without affecting performance) to generate electricity.[26] In 2008, coal-burning facilities substituted biomass for coal to generate 1.3 percent of electricity.

26. See David Ortiz and others, *Near-Term Opportunities for Integrating Biomass into the U.S. Electricity Supply* (Santa Monica, Calif.: RAND, 2011), www.rand.org/pubs/technical_reports/TR984.html.

## Electricity Pricing and Demand

Temporary disruptions in fuel supplies that cause an increase in the cost of generating electricity are unlikely to result in large price increases for households and businesses that rely on electricity. In part, that is because of the way in which increases in costs are passed on to households and businesses. Although the nature of contracts between electricity producers, distributors, and consumers varies across the United States, the electricity rates offered to households and businesses typically are regulated by a local public utility commission. Such commissions compensate for the lack of competition in the distribution of electricity to consumers by regulating changes in electricity prices.

Once or twice a year, distributors of electricity negotiate a rate change and the term for that change. Once a rate change is approved, the electricity producer is contractually required to deliver electricity at the agreed-upon rate for the duration of the contract term. For that reason, the cost of any disruption is initially borne by the producers and distributors of electricity, although it is ultimately passed on to households and businesses. Any increase in the costs to generate electricity will take several months to appear on the bills of households and businesses, by which time the extent and total cost of the outage are better understood and households and businesses have had time to make adjustments.

Households and businesses can respond to any increase in electricity prices by reducing their energy usage. Recent estimates by the Department of Energy suggest that households and businesses in the United States can reduce their energy costs by 10 percent for every 3 degrees they raise the temperature on their thermostat during the summer (or reduce the temperature during the winter).[27] Other responses also are available to households and businesses. Following the 2011 nuclear power disruptions in Japan, some businesses—for example, the University of Tokyo—reduced their peak power usage by 30 percent to 40 percent by turning off lights and air-conditioning, shutting down some elevators, and running energy-intensive processes at night.[28]

The willingness of households and businesses to make such behavioral adjustments tends to be short term in nature. Eventually, households and businesses revert to their original behaviors and pay higher costs. In response to permanent increases in electricity prices, however, households and businesses would be expected to make other types of adjustments, such as purchasing energy-efficient appliances or converting to natural

27. See Department of Energy, "Energy Savers: Thermostats and Control Systems," www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12720 (accessed August 31, 2011). Also, research from the Department of Energy indicates that the short-term elasticity of demand for electricity is -0.10, meaning that a 10 percent increase in electricity prices will reduce demand by 1 percent; in contrast, the long-term elasticity of demand is -0.50 (a 10 percent increase in electricity prices will reduce demand by 5 percent). For more details, see Steven Wade, *Price Responsiveness in the AEO2003 NEMS Residential and Commercial Buildings Sector Models* (Department of Energy, Energy Information Administration, 2003).

28. See David Cyranoski, "Japan Rethinks its Energy Policy," *Nature,* vol. 473 (May 18, 2011), p. 263.

gas for heating and cooling. Over the past several decades, for example, households and businesses have shifted away from fuel oil and to a much greater use of electricity and natural gas to provide heating (see Box 3). Although such changes take more time to implement and cost more initially, they are more difficult to reverse once they have been implemented. Also, they lessen the exposure of households and businesses to subsequent increases in electricity prices.

## Energy Security for Transportation

Disruptions in supplies of the commodities that power the transportation sector would probably impose increased costs on U.S. households and businesses because, unlike the electricity sector, the transportation sector lacks features that would allow it to more easily absorb such price increases. The primary underlying difference between the two sectors is that the transportation sector relies almost exclusively on petroleum products for its fuel, whereas the electricity sector relies on various energy sources (see Figure 8). The nation's dependence on a single source of fuel for transportation, in combination with two other features, increases its vulnerability to disruptions:

- Refineries are needed to convert oil into usable products like gasoline, diesel, jet fuel, and asphalt. Surplus refining capacity exists in the United States, but it is heavily concentrated near the Gulf of Mexico, where exposure to hurricanes or other events might disrupt the production of oil products.

- Consumers of gasoline, diesel, and jet fuel have few other options available to them over the near term to satisfy their transportation needs (see Figure 9). Thus, disruptions in oil markets or refining will cause households and businesses to pay more for their transportation fuel and raise the costs of goods and services that rely on transportation for their production.

The U.S. government can respond in a number of ways to concerns about the costs that disruptions to oil markets impose on U.S. consumers and the economy. Some of those policy options could reduce—but no policy could eliminate—the costs borne by consumers as a result of disruptions. In general, policies designed to lessen the consumption of oil (for example, greater fuel efficiency requirements) would be more effective at reducing the vulnerability of consumers to disruptions than policies designed to increase the domestic production of oil.

### Refinery Capacity

U.S. firms maintain 148 operable refineries, producing enough refined petroleum products (such as gasoline and various types of fuel oil) to make the United States a net exporter of those products in 2011, even though much of the crude oil used by such facilities is imported. Temporary or persistent disruptions at a small number of refineries could probably be accommodated by the refining industry because refineries were, on average, operating at 14 percent below full capacity (and 11 refineries were idle) in 2011. However, almost half of U.S. refining capacity is near the Gulf of Mexico, which means that a hurricane or other event that affected that area could create temporary or long-term disruptions for a large share of U.S. refining capacity. Temporary disruptions (as occurred following several hurricanes in 2005) could probably be at least partially offset by refiners' drawing down stores of refined petroleum products and would cause only temporary increases in gasoline prices. Long-term disruptions could reduce the availability of refined products. For example, many of the refineries near the Gulf of Mexico are designed to process the type of oil commonly produced in Mexico and Canada. Removing those refineries from operation would reduce U.S. capacity to refine oil from those countries (because other refiners cannot process that type of oil), which would decrease the availability of gasoline and other oil products to the U.S. market. Any event that caused refiners located near the Gulf of Mexico to temporarily or permanently shut down would increase prices for gasoline and diesel fuel for U.S. consumers.

### Consumer Demand for Oil

The ultimate vulnerability of U.S. households and businesses to disruptions in the supply of oil is determined by their ability to change their behavior when oil prices increase. In the United States, demand is relatively unresponsive to price changes in the near term because households and businesses have almost no ability to substitute one fuel for another in their transportation decisions or to substantially reduce their consumption of gasoline at low cost.[29] As a result, households and businesses are limited in their ability to reduce the costs associated with higher oil prices. Over the longer term, their flexibility increases slightly because they can make decisions that might reduce their oil consumption. For example, they could buy a more fuel-efficient vehicle (such as a hybrid vehicle, which uses both electricity and gasoline) or choose to live near public transportation or their place of employment, all of which would lessen their reliance on gasoline.

### Policy Options to Dampen the Effects of Disruptions in Oil Supplies

The interconnectedness of the world oil market means that U.S. households and businesses will always be exposed to fluctuations in the price of oil, regardless of how much oil the United States imports or produces domestically. To the extent that the United States can adopt policies that increase the ability of U.S. consumers to accommodate disruptions in oil markets, however, future supply disruptions would be less costly to U.S. households, businesses, and the economy as a whole.

29. Households and businesses could reduce their fuel use slightly by driving more slowly and less often, but demand over the near term would remain largely unchanged despite higher oil prices. Estimates of the near-term elasticity of demand with regard to the price of gasoline range between -0.03 and -0.08; in the long run, the elasticity is estimated to be about -0.4. See Jonathan E. Hughes, Christopher R. Knittel, and Daniel Sperling, "Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand," *Energy Journal*, vol. 29, no. 1 (2008), pp. 113–134; and Congressional Budget Office, *Effects of Gasoline Prices on Driving Behavior and Vehicle Markets* (January 2008).

Policies to lessen the cost of those disruptions can take two forms: They can increase the domestic production of oil or decrease the domestic consumption of oil. Fundamentally, policies that increased the domestic production of oil would have an effect on world oil prices similar to that of policies that reduced the domestic demand for oil; in economic terms, an increase of 1 million barrels per day in production with unchanged demand is generally equivalent in terms of lowering world oil prices to a decrease of 1 million barrels per day in consumption with no change in supply. Either type of policy (boosting production or reducing consumption) would increase the amount of oil available to the world market and thus tend to lower the world price of oil. In general, the response of other oil-producing countries to a price reduction is difficult to predict. To the extent that new supply or lower U.S. consumption reduced oil prices, one or more large oil-exporting countries could respond by deciding to constrain production or the development of new fields, effectively neutralizing the U.S. policy.

Many policies have been proposed to address concerns about energy security—some to address temporary disruptions, others for persistent ones. They include, for example, the following:

- Releasing oil from the Strategic Petroleum Reserve,
- Facilitating development of insurance markets,
- Promoting alternatives to personal vehicles,
- Increasing domestic oil production,
- Developing alternative fuels that substitute for oil,
- Reducing gasoline consumption from gasoline-fueled vehicles, and
- Developing vehicles that use alternative fuels.

Policies targeting one type of disruption often have some implications for the other type as well. Policies that target temporary disruptions would be applicable for addressing the transition to a persistent increase in prices. Similarly, policies that target persistent disruptions would reduce the exposure of U.S. households and businesses to subsequent temporary disruptions.

**Policies to Address Temporary Disruptions.** Policies targeting temporary disruptions in the supply of oil take two general forms:

- Reducing the exposure of consumers to high prices by, for example, making oil from the Strategic Petroleum Reserve available to the world oil market or encouraging the development of insurance markets, or

- Providing U.S. households and businesses with more choices in the near term for reducing the use of personal vehicles when oil prices rise.

Policies that aimed to decrease the use of personal vehicles would be more likely to reduce exposure to disruptions in oil markets because they would not rely on international coordination to be successfully implemented. (In contrast, policies to quickly make new supplies available to the world market would require international coordination.) Moreover, policies to decrease the use of personal vehicles would be more likely to have an extended benefit for consumers, even though they would probably be more costly to implement than making new supplies available to the world oil market.

*Release Oil from the Strategic Petroleum Reserve.* The release of oil from a large supply of stored oil would allow the United States to respond quickly to temporary oil disruptions by making additional supplies available to the world market. In 2010, U.S. stores of oil contained more than 1 billion barrels, including 727 million barrels in the SPR and the remainder in privately held inventories.[30] Releases from and deposits to private inventories occur regularly, reflecting decisions by individual firms and refineries in response to very short-term variability in their supply. The management of those inventories is not coordinated, however, so the release of their oil would probably not offset an extended disruption in production elsewhere—in Nigeria or Libya, for example. In contrast, a release from the SPR could be large enough to offset a modest disruption for several months. Such releases could constrain increases in oil prices and thus dampen any effects of those price increases on the economy.

Use of the SPR would have two disadvantages, however: First, it could be offset if other oil-producing countries reduced their output. Just as Saudi Arabia can increase production to offset temporary disruptions, it also can reduce production to offset additional supply to the market, such as releases from the SPR. In the past, Saudi Arabia and other OPEC members have stated their intention to maintain stable world oil prices and their willingness to offset additional supply to achieve that objective. Thus, before releasing oil from the SPR, U.S. officials would probably need to coordinate with Saudi Arabia to ensure that the release would not be offset. For example, following the June 2011 decision by member countries of the International Energy Agency to release 60 million barrels of oil onto the world market, Saudi Arabia increased production by about 10 percent in the three months after the release, an action probably anticipated by U.S. officials.

The release of oil from the SPR would have a greater ability to reduce oil prices if done in coordination with countries that have strategic reserves and countries that produce oil. The International Energy Agency estimates that the SPR represents about half of oil

30. The SPR was created in 1975 in response to concerns about interruptions in the supply of oil to the United States. Oil in the SPR is stored in four large underground caverns near the Gulf of Mexico; the reserve contained 696 million barrels of oil as of March 30, 2012. Large releases in response to energy supply disruptions can occur only with the authorization of the President.

reserves held around the world by oil-importing countries and available for emergency use. That total capacity for releases increases the ability of large oil-consuming countries to respond to disruptions in the supply of oil.

Second, a release of oil from the SPR would probably have little impact on world oil prices over an extended period. A unilateral release by the United States might be large enough to offset a small short-term disruption; the SPR can accommodate a maximum release of 4.4 million barrels per day for up to three months (and declining amounts thereafter).[31] However, as the United States released oil from the SPR, the world market would assume that the United States probably wanted to replenish its reserve (to afford it the capacity to respond to future disruptions), and those anticipated purchases in the future would probably increase the price of oil before the SPR was actually refilled. Moreover, a release from the SPR would not be able to offset large disruptions in oil markets. For example, a closure of the Strait of Hormuz—which would affect the availability of almost 20 percent of world oil that is traded—could not be offset by a unilateral release of oil from the SPR.

*Facilitate Development of Insurance Markets.* Establishing markets that provided consumers with insurance against increases in energy prices and encouraging the use of such markets could also serve to dampen temporarily the effects of a supply disruption on the economy. The effectiveness of such an approach would depend on how the burden of higher prices was distributed by those markets.

Consumers could pay others to make certain that gasoline and diesel prices remained within a specific range. For example, gasoline retailers could allow consumers to prepay for gasoline at prices based on future expectations of gasoline prices in the same way that some electric utilities offer customers the option to lock in electricity prices for certain periods. Under such an arrangement, consumers would pay a fee to retailers or investors who provided the insurance, which would decrease their costs if prices rose above that range, on average, but decrease their savings if prices fell below that range. Adopting a regulatory framework that encouraged the use of such insurance or even providing small subsidies for it could reduce the economywide effects of energy supply disruptions.

Such an insurance market could benefit the economy to the extent that it transferred risk from consumers of oil to investors who were better able to bear that risk. Those investors would reduce indirect costs on the economy when oil prices rose if, for example, they lived outside the United States or if they could absorb such price changes more easily than the average consumer. However, if the risk was transferred back to U.S. consumers through widely held investments, such insurance would be less effective in reducing the economic harm that would come from higher oil prices.

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31. See Anthony Andrews and Robert Pirog, *The Strategic Petroleum Reserve and Refined Product Reserves: Authorization and Drawdown Policy*, CRS Report for Congress R41687 (Congressional Research Service, March 11, 2011).

*Promote Alternatives to Personal Vehicles.* Policies that encouraged alternatives to personal vehicle use—by increasing the availability of public transportation or reducing the need to use personal vehicles—could reduce the vulnerability of U.S. households and businesses to both temporary and long-term increases in oil prices.

The availability of public transportation that could readily be used when oil prices rose would offer consumers added flexibility to respond to those increases. Research suggests that important determinants leading to the use of public transportation are the price of the trip, the door-to-door travel time, and the reliability of service.[32] To address those factors, policies could provide subsidies to reduce fares or to promote more frequent operation (beyond rush hour, assuming firms also offer flexibility in working hours) of existing rail, subway, and bus service. Such changes could motivate consumers to increase their use of public transportation when oil prices increased. And those changes could be implemented within a few weeks, if sufficient staffing and finances were available.

Creating such additional capacity for public transportation could be costly. The construction of new fixed-track public transportation alternatives (such as rail and subway lines) would require significant time and money. A less expensive alternative would be to expand existing transit systems, such as by adding new bus service or increasing the number and location of bus stops. Not all communities would be appropriate locations for public transportation offerings, however, particularly those in areas with a geographically dispersed population.

In addition, policies that reduced people's use of their personal vehicles or lessened the associated costs would ultimately decrease the vulnerability of households and businesses to disruptions in oil markets. Widespread adoption of telecommuting work policies, the implementation of lower speed limits, or the promotion of ride-sharing or bicycle programs would reduce the consumption of transportation fuel.[33] Such policies would decrease fuel use by prompting some consumers to not drive or to drive more slowly (and thus burn less gasoline per mile traveled) when they did drive. In addition, the policies could be implemented quickly (although not all at the federal level). Such policies would allow some households and businesses to lessen their expenditures

32. See Daniel McFadden, "The Measurement of Urban Travel Demand," *Journal of Public Economics,* vol. 3, no. 4 (November 1974), pp. 303–328; and Brian D. Taylor and others, "Nature and/or Nurture? Analyzing the Determinants of Transit Ridership Across U.S. Urbanized Areas," *Transportation Research Part A: Policy and Practice,* vol. 43, no. 1 (January 2009), pp. 60–77.

33. The Government Accountability Office reports that the establishment in 1974 of a national speed limit of 55 miles per hour decreased fuel consumption in the United States by 0.2 percent to 3 percent, which the Department of Energy estimates to yield a savings of 175,000 to 275,000 barrels of oil per day; a reduction of 5 miles per hour in speed increases fuel economy by between 5 percent and 10 percent. See Government Accountability Office, *Energy Efficiency: Potential Fuel Savings Generated by a National Speed Limit Would Be Influenced by Many Other Factors,* GAO-09-153R (November 7, 2008).

when oil prices rose, but they might be accompanied by reduced productivity or longer commutes.

**Policies to Address Persistent Disruptions.** Policies to address long-lasting changes in oil prices could take two broad approaches parallel to those used to address temporary disruptions:

- Increasing domestic production of oil or oil substitutes or
- Reducing the consumption of oil by, for example, increasing fuel-efficiency standards or encouraging the development of alternative transportation options that use less, or no, oil.

The first approach could lower oil prices (probably by only a small amount) on an ongoing basis but would still leave households and businesses exposed to price increases stemming from supply disruptions, although those increases would start from a lower level. The second approach would shift some households and businesses away from oil-fueled vehicles, which could reduce their exposure to disruptions in oil markets. Implementing any policy aimed at reducing vulnerability to persistent disruptions would require more time and financial resources than would implementing policies to address temporary disruptions.

*Increase Domestic Oil Production.* Policies designed to increase the domestic production of oil could lower world oil prices over the long run (though the effect would probably be small), but they would probably not reduce the vulnerability of U.S. households and businesses to disruptions in oil supplies. Such policies could include opening more of the Outer Continental Shelf or the Arctic to drilling, expediting regulatory approval of applications to drill, or reducing the fees charged to private firms (for example, the royalties paid to the government for each barrel of oil produced) when the government makes oil underlying federal lands available for extraction.[34]

Those policies would probably increase the amount of oil brought to the world market, which would lower world oil prices for the time that the additional supply was available. The magnitude of the price reduction would depend on the volume of oil produced and the response by other countries to the introduction of the new supply. To illustrate, the Energy Information Administration (EIA) estimates that opening the Arctic National Wildlife Refuge to drilling could boost domestic oil production by as much as 0.5 to 1.5 million barrels per day (an increase of 9 percent to 27 percent of U.S. production based on 2010 production levels), which could lower world oil prices by $0.41 to $1.44 per barrel in 2025, relative to a base case in which oil was $65 per barrel and assuming no change in oil production elsewhere in the world; that decline would be

34. The Outer Continental Shelf is the submerged land, subsoil, and seabed that is off the coast of the United States at a distance between state jurisdiction (typically between 3 and 5 nautical miles offshore, depending on the state) and 200 miles offshore.

expected to reduce gasoline prices by 1 to 3 cents per gallon.[35] Production would not commence until 10 years after development was first allowed, and peak production would not occur until 10 years after that. Some oil fields on land can be developed more quickly (within a few years), but deepwater oil fields are expected to have the largest quantity of oil. Such development would not be expected to offset temporary supply disruptions but could increase long-run production in the United States.

EIA further estimates that such an increase in production would be largely offset by a corresponding decrease in output from other large oil-producing countries, resulting in little observable change in the price of oil. For example, Khalid Al Falih, chief executive officer of Saudi Aramco, recently said that Saudi Arabia would reduce its planned output capacity expansion given "massive capacity expansions coming out of countries like Brazil [and] Iraq."[36]

Thus, increasing production in the United States might not increase the world's oil supply substantially or lower the price of oil significantly. For example, oil and gasoline prices have not fallen over the past few years despite an increase in U.S. oil production during that period. Moreover, because any new productive capacity in the United States would be controlled by private firms and not the government (as it is for OPEC members), that new capacity would be used in amounts determined by the owners and not necessarily held as spare capacity to offset disruptions.

U.S. government agencies estimate that the amount of oil that is technically feasible to recover in the United States is 162 billion barrels (22 billion barrels of which has already been discovered); according to recent estimates, technically recoverable oil resources in the United States are equivalent to 78 years of supply at 2010 domestic production levels, or 29 years of supply if produced at the level of current consumption.[37] Determining the effect on world prices of finding and producing additional oil is difficult, given the uncertainty inherent in bringing the oil to market and the possible reaction of other oil-producing countries.

Even if world oil prices declined as a result of increased U.S. production, most households and businesses would not be substantially less vulnerable to future oil disruptions, for two reasons. First, an expectation by consumers of sustained lower prices would provide an incentive for households and businesses to make long-run decisions—that is, decisions that cannot easily be reversed in the near term—that ultimately increased their reliance on oil. For example, a reduction in gasoline prices would decrease the

35. See Department of Energy, Energy Information Administration, *Analysis of Crude Oil Production in the Arctic National Wildlife Refuge* (May 2008). Prices are quoted in 2006 dollars.

36. Summer Said, "Saudis See No Reason to Raise Oil Output Capacity," *Wall Street Journal* (October 10, 2011).

37. See Behrens, Ratner, and Glover, *U.S. Fossil Fuel Resources*. In 2010, the United States produced 2 billion barrels of oil and consumed 5.4 billion barrels.

cost of using less-fuel-efficient vehicles or living far from work. Similarly, if industries expected lower oil prices, they would have less incentive to develop alternative fuel supplies (such as natural gas or electricity) for personal or public transportation. As a result, lower prices might induce households and businesses to increase their reliance on oil in the transportation sector and, thus, increase their exposure to disruptions in the supply of oil. Second, even though oil prices might be slightly lower if oil production was increased, a reduction in cost of a few dollars per barrel would be small compared with the price fluctuations that are common to the oil market. Between 2001 and2011, price changes of $60 to $90 per barrel of oil occurred. Thus, increased domestic production would leave the vulnerability of most consumers to disruptions in oil markets largely unchanged.[38]

Another consideration is that increased production of oil in the near term comes at the expense of a decreased capacity to produce oil farther in the future, when prices might be even higher and the ability to reduce those prices might be valued even more highly by households and businesses. Consumption of oil by China, India, and Brazil is expected to rise by 2 percent to 4 percent annually between 2008 and 2035; in contrast, oil consumption is expected to increase by 0.3 percent annually in the United States over that period.[39] Such growth in world consumption is expected to put upward pressure on oil prices (unless sufficient new sources of oil are identified and developed), causing the value of oil inventories to rise, regardless of whether that oil is held above ground or left underground in its original reservoirs. Thus, by not developing all of its oil resources now, the United States is retaining more flexibility in the future should oil prices rise dramatically.

Even though increased domestic oil production would probably not enhance U.S. energy security as defined in this report, policymakers might choose to evaluate the need for increased production according to other criteria. For example, increased domestic production on federal lands would raise royalty payments to the federal government and thus have a positive budgetary effect. To the extent that increases in domestic production reduced the price of oil, they would also lessen the revenues earned by oil-producing countries that are hostile toward the United States. Increased

38. Greater domestic production could reduce the vulnerability of some households to disruptions in oil markets. Firms that produce oil earn higher profits when oil prices increase, particularly when such disruptions do not affect firms' costs, but only the price of oil. Thus, greater production of oil in the United States would increase the profits earned by those firms that produce oil when a disruption elsewhere occurs. To some extent, those profits would be returned to U.S. households in the form of dividends, higher salaries and wages for workers of the firms producing oil, and increased domestic investment in the production and processing of oil. Those profits also would be distributed to stockholders and used for investments outside the United States. To the extent that the people who purchase fuel for transportation are not the same as those who would receive financial benefits from the firms producing oil, increases in oil prices would redistribute wealth from consumers of transportation fuel to owners of firms that produce oil regardless of how much oil is produced domestically.

39. See Department of Energy, Energy Information Administration, *International Energy Outlook 2011* (September 19, 2011), Table B4.

production of domestic oil could reduce imports of oil as long as U.S. consumption did not step up by a corresponding amount. Moreover, increased domestic oil production could boost employment and output in the United States. The short-term effects of such changes, however, would probably be small relative to the size of the U.S. economy.[40] Increased domestic production would also have negative consequences, such as a higher risk of spills and other environmental impacts.

*Develop Alternative Fuels That Substitute for Oil.* Policies that promote the development of alternative fuels—ones that can be mixed with or used instead of gasoline and diesel—could improve the ability of U.S. households and businesses to respond to permanent changes in oil prices. Examples of such policies include subsidies for the development of natural gas resources, biofuels, or coal gasification.[41] (All of those types of fuel can be mixed directly with or chemically converted to gasoline.) Persistent disruptions in oil markets could be partially or fully offset if domestic firms decided to expand their capacity to synthetically create transportation fuels, even though those fuels, because of their direct substitutability, would be sold at the same price as oil-based transport fuels. If the production of substitute fuels was sufficiently large and those fuels were held in reserve (or only subsidized when the government determined it was warranted), that domestic capacity for synthetic fuels could operate similarly to Saudi Arabia's spare capacity for producing oil. As such, the spare capacity would benefit consumers of oil around the world. If it was maintained as permanent capacity, the effect on oil prices would probably be small—similar to the effect of increased domestic oil production—because it could be offset by other oil-producing countries.

Nevertheless, policies to promote alternative fuels would involve significant uncertainties as to their economic feasibility and the consequences of their enactment. Conversion of coal, natural gas, and organic matter to gasoline is expensive, inefficient, and unproven on a large scale.[42] In addition, greater use of coal and natural gas for transportation could increase the domestic price of those commodities and thus raise costs for electricity or other energy-consuming sectors of the economy.

40. See the statement of Douglas W. Elmendorf, Director, Congressional Budget Office, before the Senate Budget Committee, *Policies for Increasing Economic Growth and Employment in 2012 and 2013* (November 15, 2011), p. 48.

41. Coal gasification is a process that converts solid coal—through several energy-intensive steps—into gasoline and diesel fuel. Natural gas can also be chemically converted to gasoline through a similar energy-intensive process.

42. For more details on the costs and feasibility of biofuels, see Congressional Budget Office, *Using Biofuel Tax Credits to Achieve Energy and Environmental Policy Goals* (July 2010). The production of biofuels has also been found to raise the cost of food; see Congressional Budget Office, *The Impact of Ethanol Use on Food Prices and Greenhouse Gas Emissions* (April 2009). And the increased reliance on biofuels introduces weather uncertainty into considerations of crop yields from one year to the next; see Darrel Good and Scott Irwin, *2007 U.S. Corn Production Risks: What Does History Teach Us?* Marketing and Outlook Brief 2010-01 (Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, March 2010).

*Reduce Gasoline Consumption by Gasoline-Fueled Vehicles.* Policies designed to reduce the demand for oil, such as raising automobile fuel-efficiency requirements or increasing the gasoline tax, could reduce the vulnerability of U.S. households and businesses to permanent changes in oil prices.

Higher fuel-efficiency standards would require the production of new vehicles that use less fuel per mile, which would reduce the exposure of U.S. consumers to disruptions in oil prices.[43] An increase in the gasoline tax would raise the cost of consuming oil-based fuels and, in doing so, provide a financial incentive for households and businesses to find long-run alternatives to consuming such fuels. Analogous to policies that would boost the production of oil, policies that reduced fuel consumption would probably also result in slightly lower fuel prices. But even with lower prices, fuel consumption under those policies would be lower, on balance.

An increase in the gasoline tax could be implemented more quickly than policies to increase fuel-efficiency standards, which would take a longer time to have a significant effect. Near-term responses to a higher gasoline tax (or to higher gasoline prices that occur for other reasons) could include carpooling, driving more slowly, or vacationing closer to home. Long-run responses could include buying smaller, more fuel-efficient cars; living closer to work or public transit; or selecting jobs on the basis of their telecommuting options. The heating industry provides an illustrative example of the speed with which a transition of that magnitude could be made: As a result of higher oil prices in the 1970s and the availability of alternative heating fuels, U.S. consumers gradually shifted over the subsequent 40 years from oil to electricity and natural gas as their primary heating fuels (see Box 3). An increase in the gasoline tax would also bring revenues into the U.S. Treasury and, thus, have a positive budgetary effect.

Such policies would be effective only to the extent that they increased the cost of consuming gasoline and, consequently, created an incentive for consumers to reduce their use of gasoline. As a result, vehicle users would pay more to consume gasoline, or vehicle producers would pay more to implement higher fuel-efficiency requirements. (Some or all of the producers' costs would probably be passed on to vehicle buyers, which would impose larger costs on certain industries, such as trucking, and on individuals who need to drive a lot.)

*Develop Vehicles That Use Alternative Fuels.* Policies that promote flexibility in the fuels that households and businesses use for transportation would reduce their vulnerability to changes in oil prices. Such policies might include the promotion of natural gas or

43. In April 2010, the National Highway Traffic Safety Administration and the Environmental Protection Agency finalized a rule to increase corporate average fuel economy standards for light-duty vehicles (including cars, sport utility vehicles, pickup trucks, minivans, and crossover vehicles) from 29.7 miles per gallon in 2012 to 34.1 mpg by 2016. Then in 2011, they issued a joint proposed rule that would further tighten corporate average fuel economy standards for those vehicles—to 49.6 mpg—from 2017 through 2025.

electric vehicles, federal support for high-speed electric rail, or new public transportation relying on alternative fuels. To the extent that those policies diversified the sources of energy used in the transportation sector, they would reduce the vulnerability to changing world oil prices for those consumers who would shift away from using oil for transportation—as well as for those consumers who would still ordinarily use oil—by offering them additional transportation alternatives that are not dependent on oil. Some limited steps have already been taken toward diversifying fuel use for transportation; for example, municipal vehicles rely increasingly on natural gas.

Some policies to develop vehicles that use alternative fuels could require significant investments in infrastructure and technology and, thus, might not produce a positive return for many years, if at all. Development of a distribution network to deliver natural gas to vehicles and construction of high-speed rail would both have high capital costs, which would probably have to be borne at least partially by taxpayers. In addition, as the transportation sector came to rely more heavily on other commodities, such as natural gas, those commodities could increase in cost, which might raise costs for consumers in other energy-consuming sectors of the economy.

**Table 1.** Return to Reference

## Energy-Consuming Sectors of the U.S. Economy, 2010

| Sector | Energy Expenditures (Percentage of GDP) | Total Energy Use (Percent) | Primary Sources of Energy |
|---|---|---|---|
| Transportation | 3.6 | 28 | Oil (for gasoline, diesel, and jet fuel) |
| Electricity | 2.4 | 40 | Coal, natural gas, nuclear power, and renewable sources |
| Industrial Processing | 1.5 | 16 | Natural gas, oil, coal, and renewable sources |
| HVAC | 0.8 | 15 | Natural gas, oil, and renewable sources |
| **Total** | **8.4** | **100** | |

Source: Congressional Budget Office's calculations based on data from Department of Energy, Energy Information Administration, *Short-Term Energy Outlook* (February 7, 2012) and *Annual Energy Review 2010* (October 19, 2011).

Notes: Industrial processing includes the nonfuel use of energy commodities as inputs in the production of plastics, resins, fertilizers, metals, and other chemicals.

Renewable sources of energy include hydropower, wood, biofuels, wind, waste, geothermal, and solar.

GDP = gross domestic product; HVAC = heating, ventilation, and air conditioning.

## Table 2.

Return to Reference

# Production of Oil and Consumption of Oil Products

(Millions of barrels per day, estimated, in 2010)

| Top 20 Countries That Produce Oil | | | Top 20 Countries That Consume Oil Products | |
|---|---|---|---|---|
| 1 | Russia | 9.7 | United States | 19.2 |
| 2 | Saudi Arabia[a] | 8.9 | China | 9.4 |
| 3 | United States | 5.5 | Japan | 4.5 |
| 4 | Iran[a] | 4.1 | India | 3.1 |
| 5 | China | 4.1 | Russia | 3.0 |
| 6 | Canada | 2.7 | Saudi Arabia | 2.7 |
| 7 | Mexico | 2.6 | Brazil | 2.6 |
| 8 | Nigeria[a] | 2.5 | Germany | 2.5 |
| 9 | United Arab Emirates[a] | 2.4 | South Korea | 2.3 |
| 10 | Iraq[a] | 2.4 | Canada | 2.2 |
| 11 | Kuwait[a] | 2.3 | Mexico | 2.1 |
| 12 | Venezuela[a] | 2.1 | France | 1.9 |
| 13 | Brazil | 2.1 | Iran | 1.8 |
| 14 | Angola[a] | 1.9 | United Kingdom | 1.6 |
| 15 | Norway | 1.9 | Italy | 1.5 |
| 16 | Libya[a] | 1.7 | Spain | 1.4 |
| 17 | Algeria[a] | 1.5 | Indonesia | 1.4 |
| 18 | Kazakhstan | 1.5 | Singapore | 1.1 |
| 19 | United Kingdom | 1.2 | Netherlands | 1.0 |
| 20 | Qatar[a] | 1.1 | Australia | 1.0 |
| | Other | 11.7 | Other | 20.0 |

Source: Congressional Budget Office based on data from Department of Energy, Energy Information Administration, "International Energy Statistics: Crude Oil Production Including Lease Condensate, All Countries" and "International Energy Statistics: Total Petroleum Consumption, All Countries" (April 23, 2012).

Note: Production numbers represent the volume of oil produced from reservoirs underground. During processing, additives and other refining steps contribute to a larger volume of oil products relative to the oil inputs. Consumption numbers represent the volume of oil products consumed, including gasoline, diesel, and jet fuel.

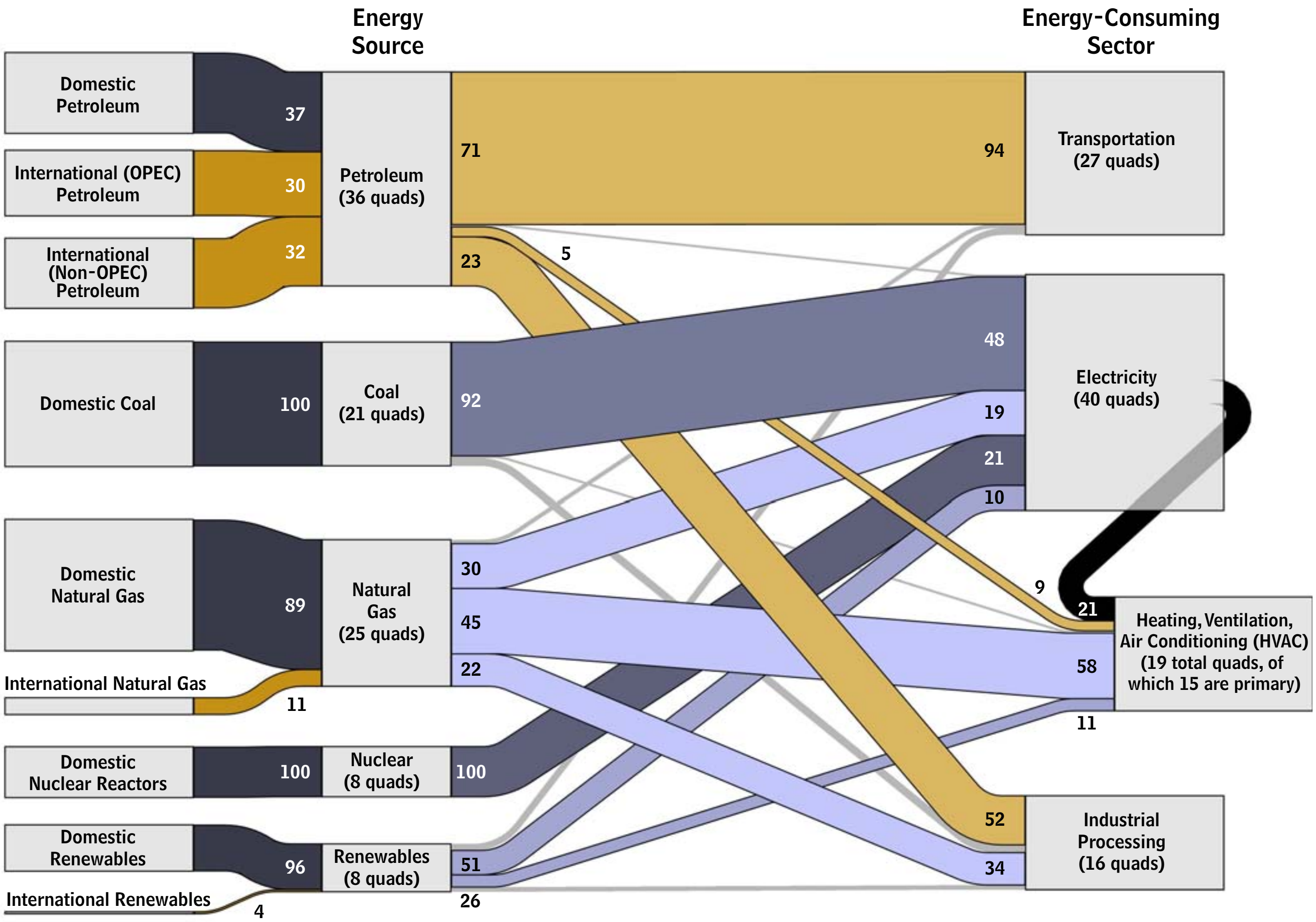
a. Indicates membership in the Organization of Petroleum Exporting Countries (OPEC). The only OPEC country not included in the list of producers above is Ecuador. Collectively, OPEC members produced 32 million barrels of oil per day in 2010 and consumed 8 million barrels of oil products per day.

**Figure 1.**

Return to Reference

## Energy Flows, by Source of Energy and Energy-Consuming Sector, 2010

(Percent)




Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration (www.eia.gov).

Notes: Unlabeled flows represent amounts of less than 10 percent, except in the renewables category, where the unlabeled flows are less than 15 percent. In the HVAC sector, primary energy is that which comes directly from one of the five energy sources; total energy is primary energy plus electricity used for HVAC.

OPEC = Organization of Petroleum Exporting Countries; quad = a unit of energy equal to a quadrillion British thermal units.

**Figure 2.**

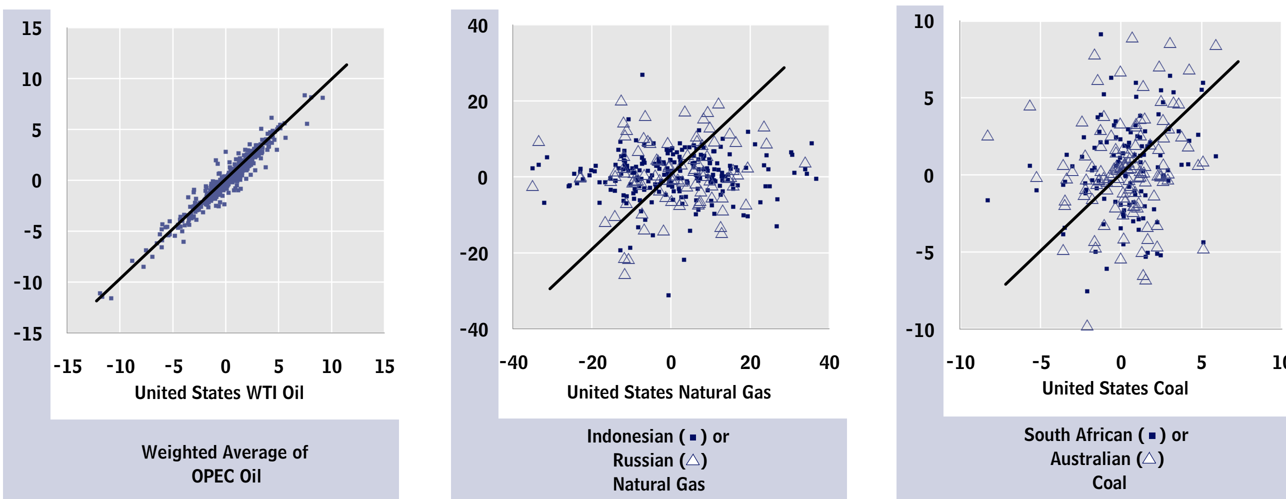
Return to Reference 1, 2, 3

## Comparison of Changes in Prices for Crude Oil, Natural Gas, and Coal in the United States and in Other Countries

**Change in Weekly Crude Oil Price, 1997 to 2011 (U.S. dollars per barrel)**

**Change in Monthly Natural Gas Price, 2001 to 2011 (U.S. dollars per thousand cubic feet)**

**Change in Monthly Coal Price, 2001 to 2011 (U.S. dollars per metric ton)**




Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, "World Crude Oil Prices," July 13, 2011 (for oil prices); and Bloomberg (for monthly data on prices for coal and natural gas).

Notes: The diagonal line through each graph at 45 degrees indicates when changes in prices in the markets being compared correspond exactly.

For natural gas, U.S. data are for Henry Hub natural gas, the price for Russian gas is for natural gas delivered to the border of Germany, and the price for Indonesian gas is for liquefied natural gas delivered to Japan. U.S. coal is a representative coal produced in the United States, South African coal is coal produced in Richards Bay, and Australian coal is represented by an index of all coal used in the production of electricity in Australia.

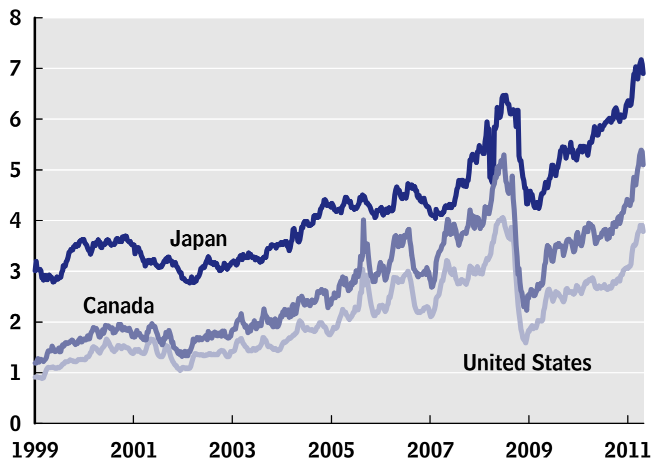
OPEC = Organization of Petroleum Exporting Countries; WTI = West Texas Intermediate.

**Figure 3.**

Return to Reference

## Average Retail Gasoline Prices in Three Countries

(Nominal dollars per gallon)



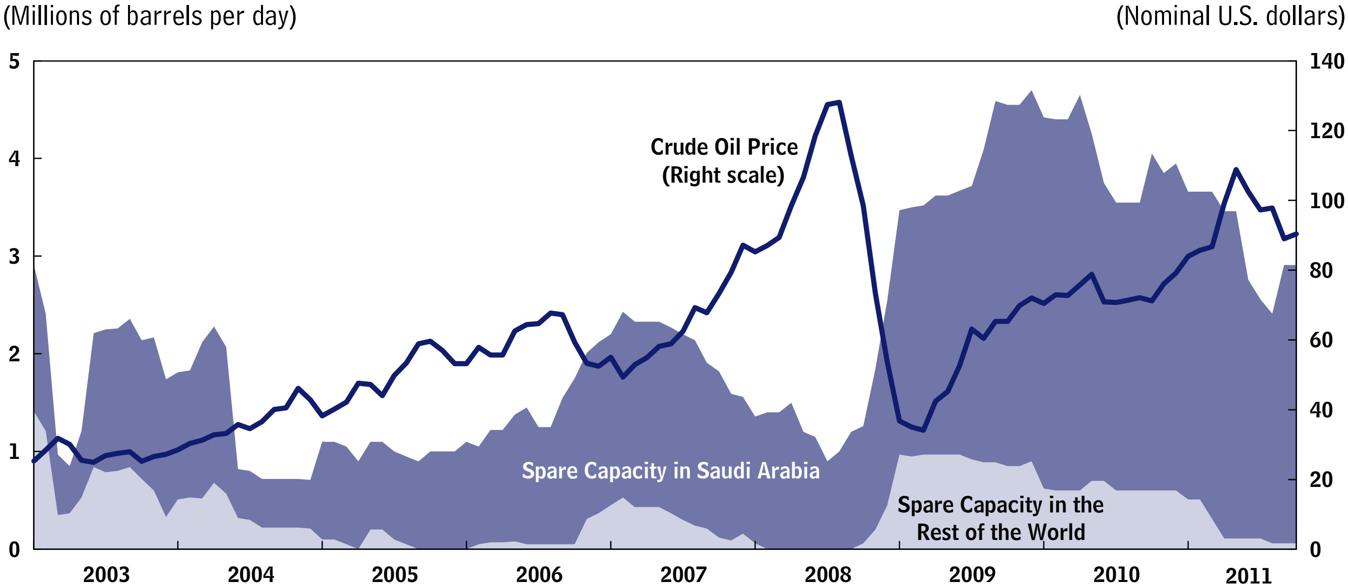

Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, "U.S. Regular Weekly Retail: Weekly U.S. Regular Conventional Retail Gasoline Prices," November 21, 2011 (for U.S. gasoline prices); Natural Resource Canada, "Average Retail Prices for Regular Gasoline in 2011," November 2011 (for average Canadian gasoline prices); and The Institute of Energy Economics of Japan, "The Oil Information Center," November 2011, http://oil-info.ieej.or.jp/price/price.html (for regular gasoline prices averaged across Japan).

Notes: Absolute differences in gasoline prices between countries vary because of different fees and taxes imposed over time by the countries.

Over the period shown above, Canada was a net exporter of oil, the United States produced 30 percent to 40 percent of the oil it used, and Japan produced almost no oil.

**Figure 4.** Return to Reference

## Spare Oil Production Capacity in Saudi Arabia and in the Rest of the World, and the Price of Crude Oil



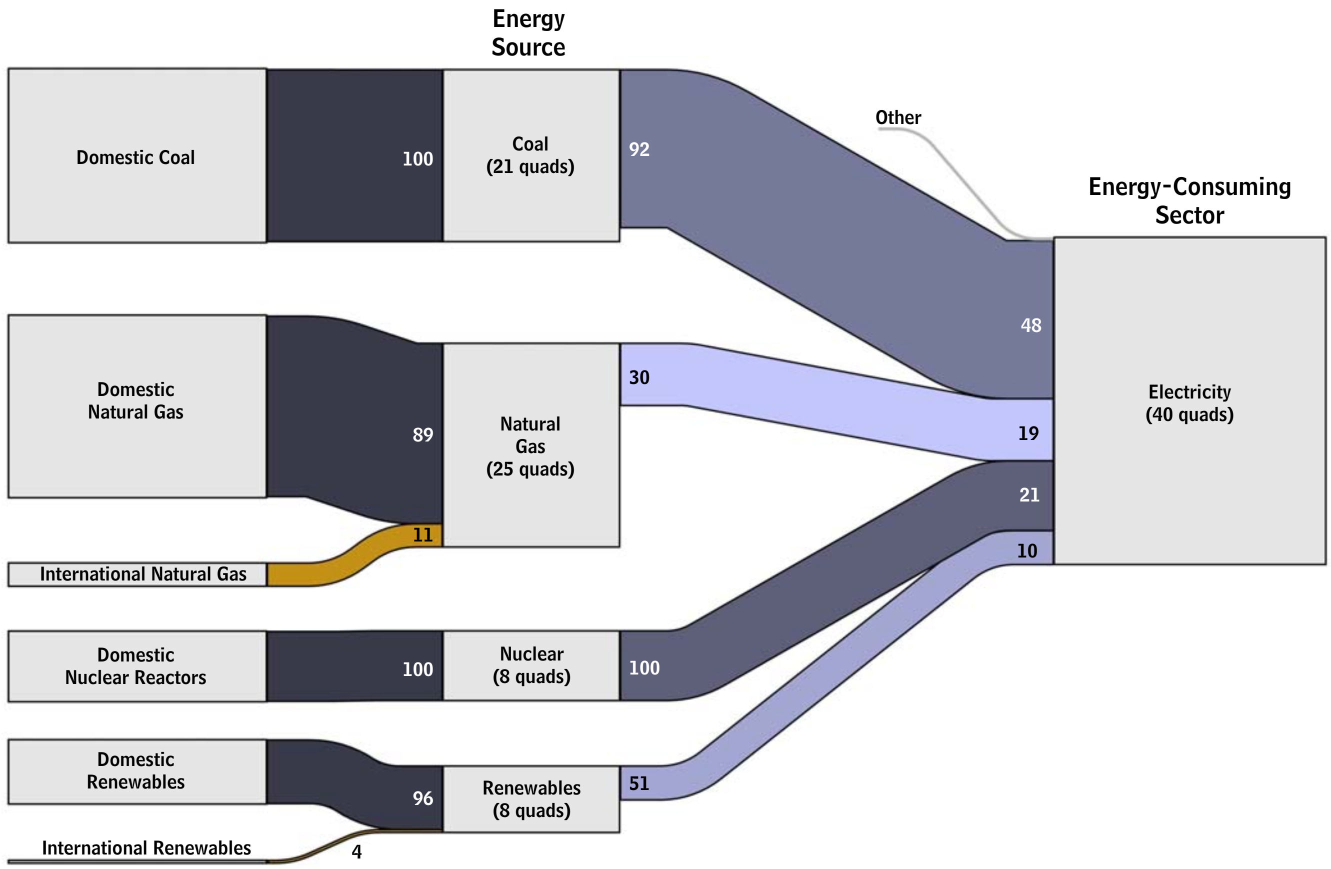

Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, "Short-Term Energy Outlook," January 4, 2012, www.eia.gov/forecasts/steo/query/index.cfm (for spare production capacity), and "World Crude Oil Prices," January 4, 2012 (for prices of West Texas Intermediate crude oil).

**Figure 5.**

Return to Reference

## Energy Flows for the Electricity Sector, 2010

(Percent)




Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration (www.eia.gov).

Notes: The flow labeled "Other" represents about 1 percent of electricity energy input, primarily from oil.

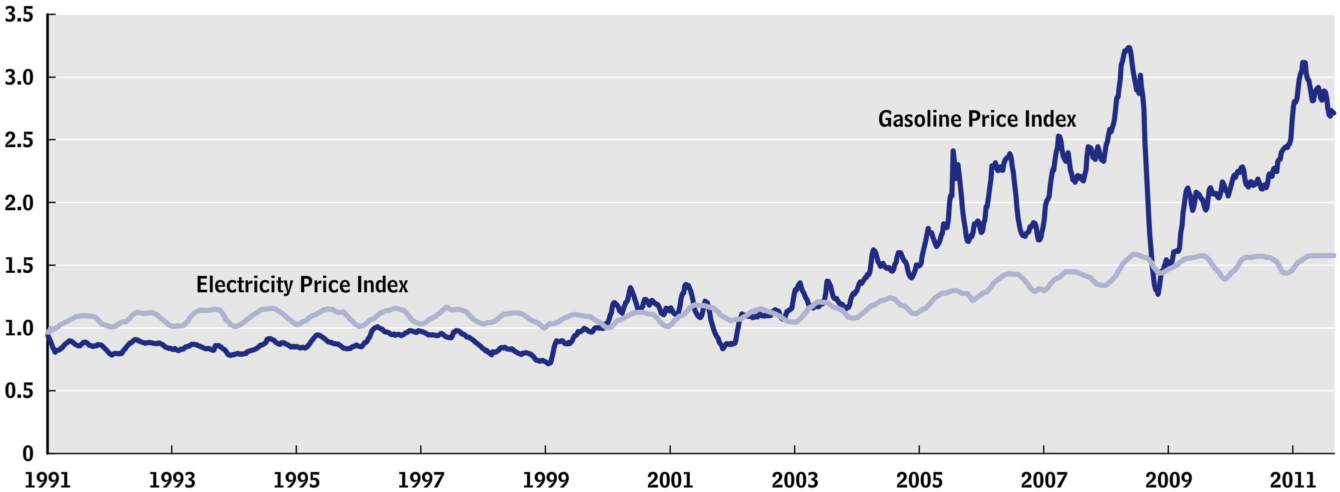
quad = a unit of energy equal to a quadrillion British thermal units.

**Figure 6.**

Return to Reference

## Prices for Gasoline and Electricity in the United States

(January 2000 = 1.0)




Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, "U.S. Regular Weekly Retail: Weekly U.S. Regular Conventional Retail Gasoline Prices," November 21, 2011 (for gasoline prices), and "Detailed Sales and Revenue Data by State, Monthly Back to 1990," November 2011 (for electricity prices).

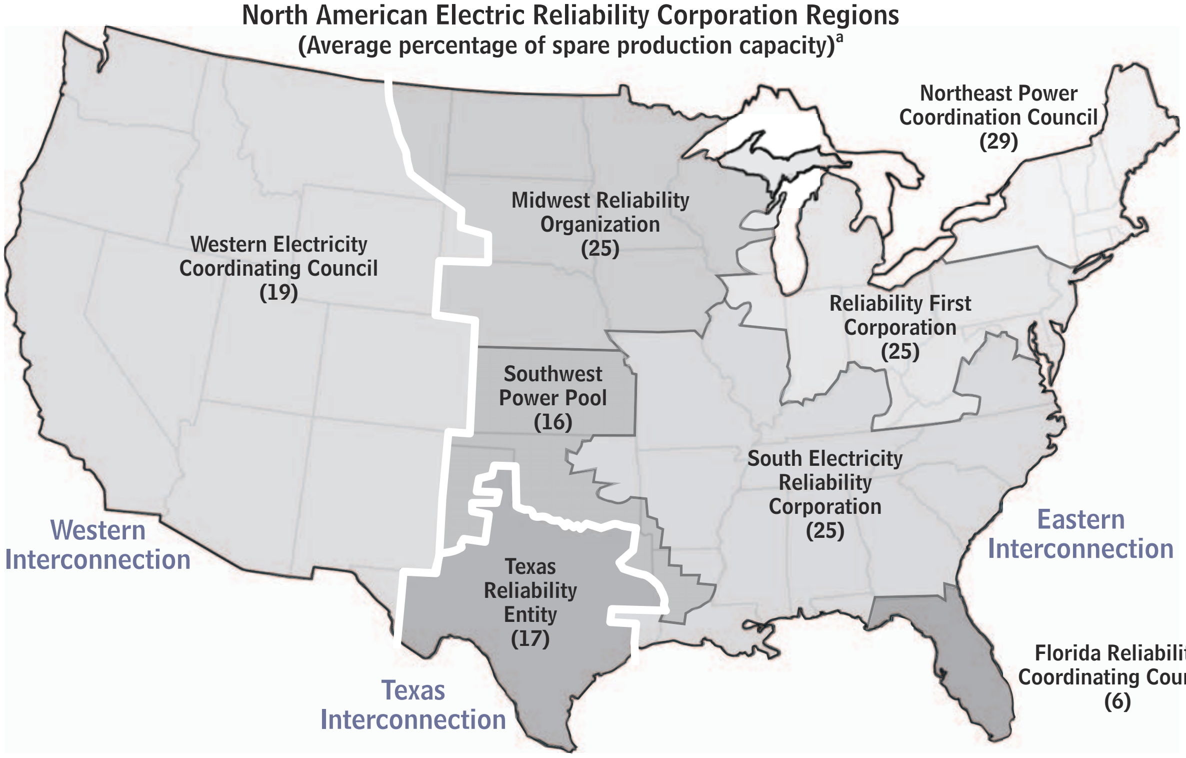
Note: The price indexes for gasoline and electricity were created by dividing all historical prices by their respective price on January 1, 2000.

## Figure 7.

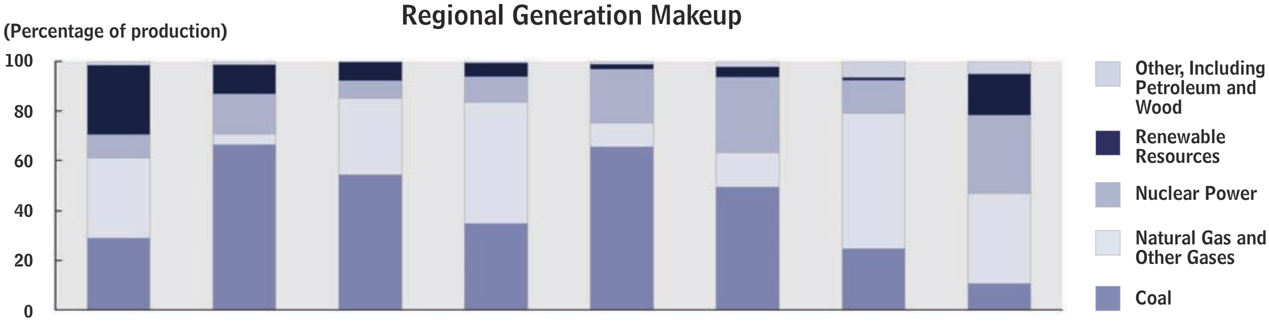
Return to Reference

# The Electricity Sector in the United States, 2009

### North American Electric Reliability Corporation Regions
(Average percentage of spare production capacity)[a]




### Regional Generation Makeup




### Number of Nuclear, Natural Gas, and Coal Plants

| | Western Electricity Coordinating Council | Midwest Reliability Organization | Southwest Power Pool | Texas Reliability Entity | Reliability First Corporation | South Electricity Reliability Corporation | Florida Reliability Coordinating Council | Northeast Power Coordination Council |
|---|---|---|---|---|---|---|---|---|
| Nuclear Power | 4 | 7 | 1 | 2 | 14 | 26 | 3 | 8 |
| Natural Gas and Other Gases | 459 | 158 | 104 | 174 | 259 | 400 | 94 | 198 |
| Coal | 65 | 95 | 15 | 18 | 173 | 185 | 15 | 22 |

Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, www.eia.gov/cneaf/electricity/chg_str_fuel/html/fig02.html (map shown is an approximation of regions); "Electric Power Annual 2009: Table 4.3, Net Internal Demand, Actual or Planned Capacity Resources, and Capacity Margins by North American Electric Reliability Corporation Region, Summer," November 23, 2010 (for spare production capacity); "State Historical Tables for 2009: Net Generation by State by Type of Producer by Energy Source," November 23, 2010 (for regional generation makeup); and "State Historical Tables for 2009: Existing Capacity by Energy Source," November 23, 2010 (for the number of plants).

Note: The number of plants in each North American Electric Reliability Corporation (NERC) region is approximate because the number of plants is provided on a statewide basis and NERC boundaries do not coincide with state boundaries.

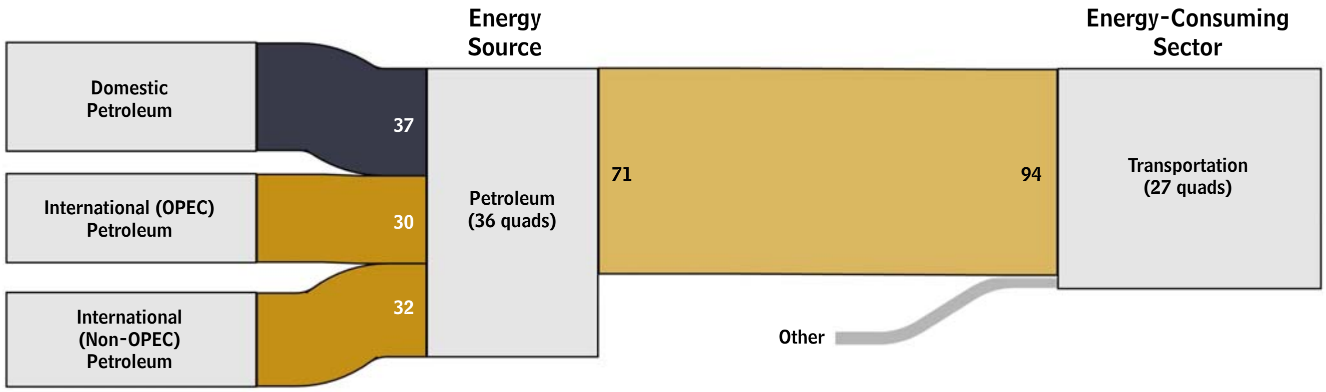
a. Spare production capacity is as reported to the Energy Information Administration.

**Figure 8.**

Return to Reference

## Energy Flows for the Transportation Sector, 2010

(Percent)




Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration (www.eia.gov).

Notes: The flow labeled "Other" represents about 6 percent of transportation energy input, primarily from natural gas and renewables.

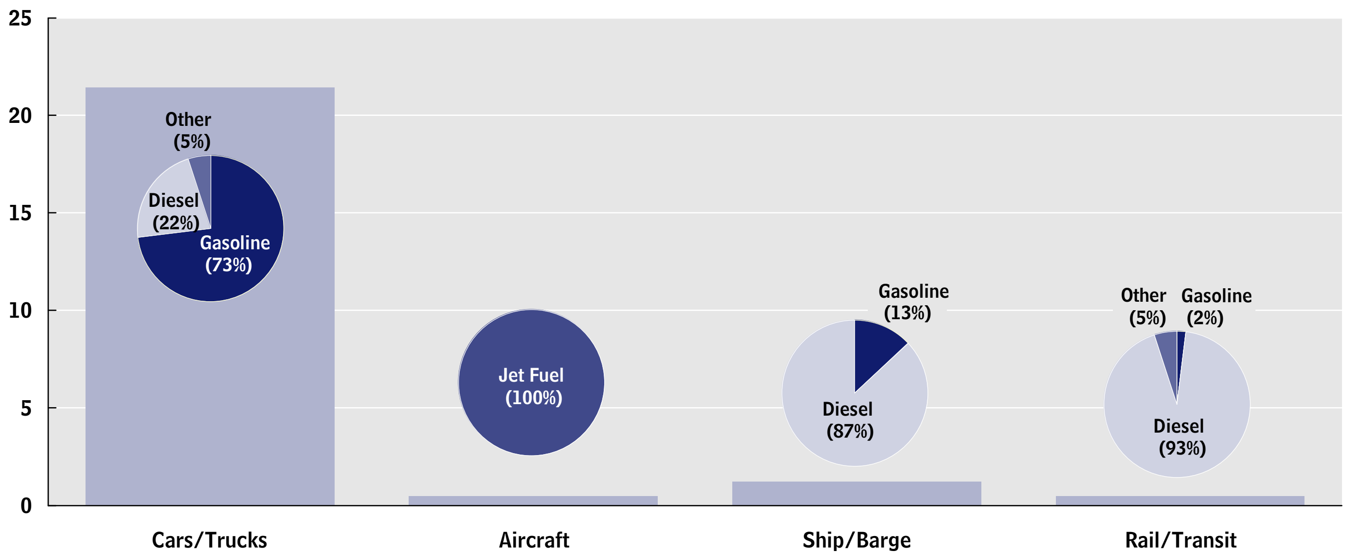
OPEC = Organization of Petroleum Exporting Countries; quad = a unit of energy equal to a quadrillion British thermal units.

**Figure 9.**

Return to Reference

## U.S. Usage of Fuel for Transportation, 2009

(Amount of energy consumed, in quads)




Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, "Estimated Consumption of Vehicle Fuels in the United States, by Fuel Type," November 2011, www.eia.gov/cneaf/alternate/page/atftables/attf_c1.html; and Bureau of Transportation Statistics, Research and Innovative Technology Administration, National Transportation Statistics, Table 4-5, "Fuel Consumption by Mode of Transportation in Physical Units," November 2011, www.bts.gov/publications/national_transportation_statistics/html/table_04_05.html.

Notes: A quad is a unit of energy equal to a quadrillion British thermal units. The Energy Information Administration includes pipelines as a type of transportation. Pipelines consume natural gas (0.6 quad) and are used to transport natural gas and oil around the country. Unspecified military use consumes an additional 0.7 quad of energy.

For the cars/trucks category, "Other" includes ethanol (0.83 quad), natural gas (0.04 quad, including liquefied natural gas, compressed natural gas, and liquefied petroleum gas), biodiesel (0.04 quad), and electricity and hydrogen (less than 0.01 quad); for the rail/transit category, "Other" includes electricity (0.02 quad) and compressed natural gas (0.01 quad).

**Box 1.**

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## Oil Independence and the Worldwide Oil Market

The worldwide market for oil makes it almost impossible for a large country like the United States to gain independence, or separation, from that market. In the United States, decisions about how much oil to import are made not by the government, but by private firms that extract, refine, and sell products made from oil—for example, gasoline, diesel, and jet fuel—to households and businesses. Those private firms enter into trading arrangements with other private firms or governments that produce oil based on the profitability and legality of such arrangements. For example, private U.S. firms produce much of the oil exported by Chad, but they are prohibited from purchasing oil from Iran because of U.S. trade sanctions against that country. Despite those sanctions, U.S. households and businesses still benefit from Iran's production of oil as long as Iran is able to sell its oil to other countries and firms that, in turn, require less oil from elsewhere in the world. (The largest importers of Iranian oil in 2008 were Japan, China, and India.)

The worldwide market for oil means that the demand for oil by consumers around the world will be satisfied with the least expensive oil, after accounting for transportation costs, quality, and trade sanctions, regardless of where it is produced. Disruptions in oil production in one country will cause the world oil market to readjust so that all countries and firms continue to receive oil at the new prevailing price. For example, in 2002, strikes in Venezuela—a large exporter of oil to the United States—reduced Venezuelan production by more than 60 percent. As a result, U.S. refiners purchased more oil from other countries or firms, and Venezuela began importing oil so that it could deliver oil to U.S. firms and other foreign parties with whom it had entered into contracts.

U.S. independence from the worldwide market for oil would require a degree of isolation that is almost certainly not feasible or desirable in such a global economy. The United States produces only about 40 percent of the oil it needs to satisfy U.S. consumer demand; thus, the United States cannot shut itself off from the world market without causing a shortage in U.S. supplies of oil and a resulting large and rapid increase in the price of oil and its products. As long as the United States imports oil, even in small quantities, the price of oil—whether imported or produced domestically—will be set in the world market.

Even if the United States produced all of its oil, it could only cut itself off from the world market and its price fluctuations by prohibiting private firms from trading internationally (which would violate rules of the World Trade Organization). But such a strategy would require the periodic discovery of large oil fields in the United States coupled with a reduction in per capita U.S. oil consumption. Moreover, some multinational oil firms would probably respond to such a strategy by making decisions about where to explore for new oil fields on the basis of whether the price of oil was higher in the United States or elsewhere. Those investment decisions would probably reflect any differences between oil prices (that is, firms would respond to higher prices in the United States with more U.S. investment) and, through their effects on supply, would serve to connect global price movements to the U.S. market, despite U.S. efforts aimed at avoiding that outcome.

**Box 2.** Return to Reference

## Disruptions in the Delivery of Electricity

Although electricity providers have significant capacity to absorb disruptions in the fuel supply, such capacity is not unlimited; an extended outage or large multiplant disruption (such as the loss of many regional plants following a severe weather event) would threaten reliability in a region, particularly during times of peak electricity usage in summer or winter months. In the past decade, there have been multiple examples of events that prevented electricity providers from delivering adequate power to businesses and households, resulting in rolling blackouts (or periods when power was not delivered to certain areas). For example, an unexpected cold spell in Texas in February 2011 caused the natural gas pipeline there to lose pressure, reducing its flow to electricity producers that use natural gas. As a result, 82 power plants temporarily shut down, and parts of the state experienced a day of rolling blackouts. Blackouts also occurred in California during its 2000–2001 energy crisis, when demand rose to record levels and supply from hydropower dropped. In both of those situations, events strained regional providers beyond the point at which spare capacity could be tapped to resolve the stress. Most other commonly known incidents of blackouts—including the 2003 blackout that affected 55 million people in the Northeast for several days—involve transmission issues, which can be caused by a storm or other event that compromises the integrity of the transmission grid.

**Box 3.** Return to Reference 1, 2

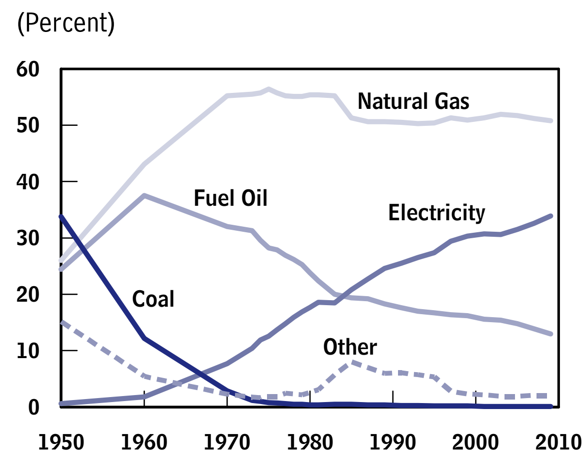
## Reduced Vulnerability to High Heating Costs

Appliances used for heating, ventilation, and air conditioning (HVAC) expose households and businesses to changes in the price of natural gas, oil, electricity, and renewable sources of power, all of which are used to run those appliances. The energy used for HVAC accounts for 15 percent of energy consumption in the United States (excluding electricity; when electricity is included, HVAC accounts for 19 percent of energy consumption). HVAC represents the third-largest sector (after transportation and electricity) of U.S. energy consumption.

Over the past several decades, in response to vulnerability to disruptions in the world oil market and resulting higher prices for oil, U.S. households and businesses have shifted to furnaces and boilers that rely more on electricity and natural gas and less on oil for heating buildings. In the 1950s, about 60 percent of heating was fueled by oil and coal (see the figure). The use of oil as a fuel source for heating peaked in the early 1960s and has since declined, most rapidly during the 1970s, when oil prices were particularly high. The use of coal as a fuel source for heating fell in the 1950s and 1960s because it was difficult to handle compared with alternatives and because it contributed more to indoor air pollution. Such transitions illustrate how long-run adaptations can occur within a sector when consumers are exposed to higher prices. As a result of those changes, U.S. households and businesses are less vulnerable to disruptions in the supply of heating fuels today than they were in the 1950s, 1960s, and 1970s.

Nevertheless, individual households and businesses in certain regions of the country that remain dependent on specific fuels may experience periods of high prices for the fuels they use. That exposure to disruptions could be particularly burdensome if, for example, a cold spell that caused periods of high heating use occurred at the same time as a disruption in the supply of oil that caused oil prices to increase. Households and businesses in the Northeast—where the use of oil for heating tends to be concentrated—are more vulnerable in that regard than households and businesses elsewhere that have largely transitioned to other sources of fuel.[44]

**Sources of Fuel for Heating**




Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, *Annual Energy Review 2010*, Table 2.7, "Type of Heating in Occupied Housing Units, Selected Years, 1950–2009" (October 19, 2011).

Notes: Fuel oil includes kerosene and liquefied petroleum gas.

Other sources of fuel include wood (the source of the spike between 1983 and 1995), solar power, briquettes, coal dust, waste material, and purchased steam.

44. See Department of Energy, Energy Information Administration, "Household Heating Fuels Vary Across the Country," *Today in Energy* (October 28, 2011), and "State Heating Oil and Propane Program Season Begins," *Today in Energy* (October 19, 2011).

# About This Document

This Congressional Budget Office (CBO) report was prepared at the request of the Chairman of the Senate Committee on Energy and Natural Resources. In keeping with CBO's mandate to provide objective, impartial analysis, this report makes no recommendations.

Andrew Stocking of CBO's Microeconomic Studies Division wrote the report under the guidance of Joseph Kile and David Moore (formerly of CBO). Bob Arnold, Perry Beider, Terry Dinan, Wendy Edelberg, Kathy Gramp, Mark Hadley, Mark Lasky, Chad Shirley, Natalie Tawil, and Steven Weinberg of CBO provided helpful comments on drafts.

Several external reviewers also provided useful comments: James Hamilton of the University of California, San Diego; Tancred Lidderdale of the Energy Information Administration; Adele Morris of The Brookings Institution; Michael Ratner of the Congressional Research Service; Bob Ryan of Limehouse Research & Trading; and Catherine Wolfram of the University of California, Berkeley. (The assistance of external reviewers implies no responsibility for the final product, which rests solely with CBO.)

Christine Bogusz edited the report. Maureen Costantino took the cover photo, and she and Jeanine Rees prepared the report for publication. The report is available on CBO's Web site (www.cbo.gov).

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Director

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