

## Searching for Alternative Energy Solutions

The United States consumes a great deal of energy in support of the world's largest economy. It produces over 70 quadrillion British Thermal Units (or "Btu," a measure of energy) of primary energy per year—mainly from coal, natural gas, petroleum, and nuclear power—and it consumes 100 quadrillion Btu, more than any other country in the world. The difference—30 quadrillion Btu—is imported, mostly in the form of petroleum. For energy security reasons, the United States seeks to diversify its energy sources and fuels. One way to do this is to pursue the use and development of domestically-produced alternative energy sources. The United States has also been concerned about the environmental effects of current energy use, particularly the emission of air pollutants and carbon dioxide (CO<sub>2</sub>). For this reason, the United States has pursued the use of alternative energy sources that have the potential to produce lower emissions than traditional fossil fuels (coal, natural gas, and petroleum), which are the source of about 85 percent of the energy consumed in the United States. Therefore, both energy security and environmental concerns motivate the consideration of policies that diversify our sources of energy. For purposes of this discussion, alternative energy will be defined as alternatives to fossil fuels and will include renewable energy sources (hydroelectric, geothermal, solar, wind, and biomass), as well as nuclear power and emerging technologies.

Alternative energy sources are not the only way to address energy security and environmental concerns. Improved energy efficiency could reduce our energy demand as well as reduce pollution. Environmental concerns could also be addressed by developing ways to use fossil fuels in a less polluting manner, such as through clean coal and carbon capture and storage (CCS) technologies. These are both very important solutions that the Administration is pursuing in tandem with alternative energy solutions; however, this chapter will focus on alternatives to fossil fuel.

This chapter will concentrate on two sectors: electricity generation and transportation. These are not the only two sectors that could benefit from alternative energy. Primary energy consumption (that is, the direct use of energy before it has been subjected to any conversion) can be divided into five major sectors: electricity generation, transportation, and energy end use by industry, commerce and residences. The potential for the direct use of alternative energy by industry, commerce and residences is important; but,

because nearly 70 percent of petroleum is used in the transportation sector and the vast majority of coal is used for electricity generation, this chapter will largely focus on these two sectors.

Alternatives for electricity generation include nuclear power, hydropower, biomass, wind, geothermal, and solar power. Alternatives in the transportation sector include developing domestically-produced transportation fuels such as ethanol and biodiesel, and finding new ways to power our cars, such as using electricity for plug-in hybrids or using hydrogen to deliver energy. Our goal over the next several decades is to change the way in which we produce and consume energy for electricity generation and transportation so as to diversify our energy sources. The key points of this chapter are:

- The current suite of available alternative energy sources is an important part of achieving our goal, but a number of technical, regulatory, and economic hurdles must be overcome to use them fully.
- There are several promising, but currently unproven, methods of producing and delivering energy that, if successfully developed and deployed, will greatly enhance our Nation's energy portfolio.
- Appropriate and limited government action can play a useful role in helping to realize our energy security goals.

## Energy Sources

The drive for alternative energy is almost a return to our roots, because energy derived from wood biomass is perhaps the oldest source of energy. Two hundred years ago, wood supplied nearly all of our energy needs. It is only over the past two centuries that fossil fuels—fuels formed from the remains of plants and animals—began to dominate as our preferred energy source.

Coal began to be used as a fuel in the 1700s for a number of reasons, including the fact that it burned cleaner and hotter than wood charcoal. Its use spread to the United States during the Industrial Revolution in the early 19<sup>th</sup> Century, increased with the introduction of steamships and steam-powered railroads, and finally was used for electricity generation in the 1880s.

The market for natural gas developed from 'town gas,' synthesized from coal and used for street and house lighting during the 1800s, and in the 1820s the first well was dug to extract natural gas. In the 1890s, electricity began to replace natural gas for lighting purposes, but beginning in the 1940s, a continental-scale pipeline system evolved to distribute these reserves to urban areas for residential space and water heating, and ultimately for power generation.

The first U.S. oil well was drilled in 1859 in Western Pennsylvania, which spawned the domestic oil industry. After World War II, domestic oil production continued to rise, but failed to keep pace with accelerating consumption. The United States became a net importer of crude oil in 1950. The huge post-war expansion of petroleum consumption in Europe and the Far East was met from foreign sources, notably Iran and Saudi Arabia, while the United States itself became increasingly dependent on petroleum imports. U.S. oil production peaked in 1970, and since then declining domestic oil production and rising domestic consumption have increased petroleum imports. While there have been significant gains in energy efficiency, economic growth in the United States has led to large increases in aviation, trucking, and automobile transportation, and has resulted in increased oil consumption.

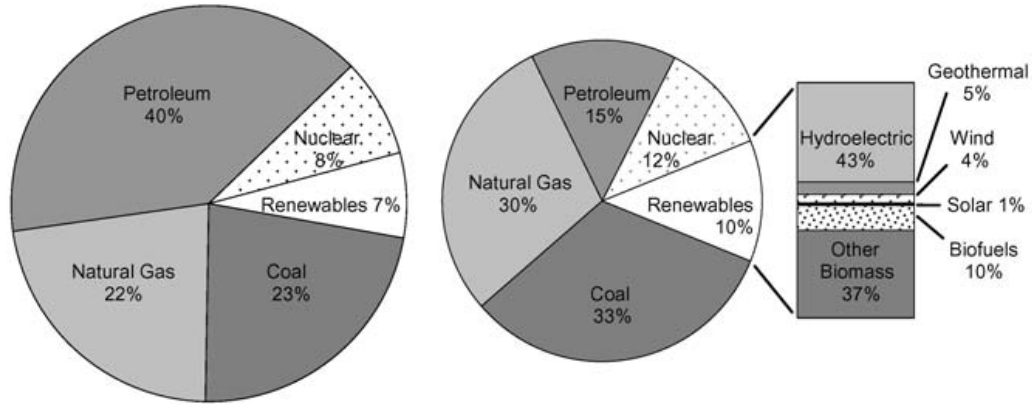
While fossil fuels have been the primary source of energy for over a century, alternative energy has been used throughout our history. The first electric car was constructed as early as the 1830s. Hydropower in the form of waterwheels for milling has been used throughout the world for centuries but dramatically increased in the United States in the 1800s with advancements in turbine technology. The first use of hydroelectric power occurred in 1880 at the Wolverine Chair Factory in Grand Rapids, Michigan, and the first U.S. commercial hydroelectric power plant opened in 1882 on the Fox River in Wisconsin. In 1888, the first large windmill was used to generate electricity in Cleveland, Ohio. In 1896, Henry Ford's first car was constructed to run on ethanol. The first commercially available solar water heaters were produced in California in the 1890s. The basis for nuclear power originated in 1942 when Enrico Fermi and other scientists created the first self-sustaining nuclear reactor at the University of Chicago, and the world's first full-scale commercial reactor opened in Cumberland, England in 1956. Today, we continue our search for alternative energy solutions in order to diversify our energy portfolio.

## Fossil Fuels

Petroleum accounts for 40 percent of the Nation's total energy consumption (see Chart 7-1), the largest share of any fuel type, and produces almost 40 quadrillion Btu of energy. (A gallon of gasoline contains about 115,000 Btu, while a kilowatt-hour of electricity is equal to 3,413 Btu.) The United States consumes about 20.7 million barrels of petroleum per day, making us the largest oil consuming country in the world. In fact, the United States consumes about 25 percent of the 84.7 million barrels consumed each day worldwide, almost three times the amount of oil consumed by China, the second largest oil-consuming nation. However, China's oil consumption has grown at an average rate of 6.3 percent per year since 1982 compared to an average rate of 1.3 percent per year for the United States.

**Chart 7-1 U.S. Energy Consumption and Production (2006)**

Fossil fuels accounted for the majority of U.S. energy consumption and production in 2006.



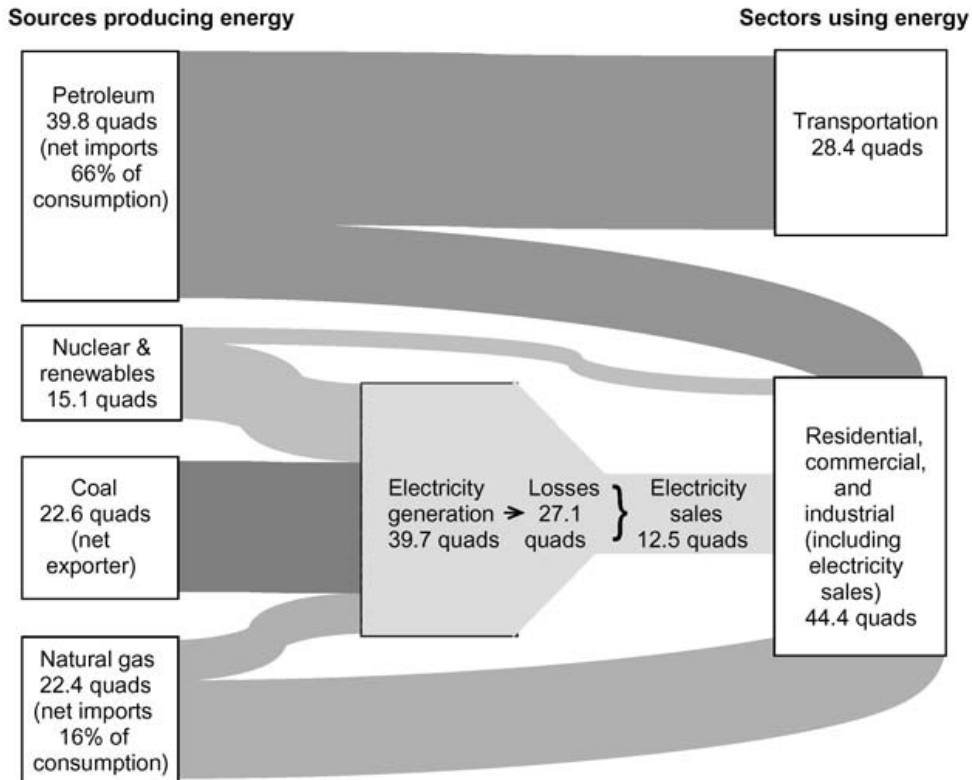
Total Consumption: 100 Quadrillion Btus

Total Production: 71 Quadrillion Btus

Source: Department of Energy (Energy Information Administration).

**Chart 7-2 U.S. Energy Consumption by Source and Sector (2006)**

The United States consumed 100 quadrillion Btu (quads) of energy in 2006.



Note: This chart does not depict some smaller energy flows, including 2.1 quads of coal consumption by residential, commercial, and industrial sources; 0.6 quads of petroleum consumption by the electricity-generation sector; and 0.6 quads of natural gas and 0.5 quads of renewables consumption by the transportation sector.  
Source: Department of Energy (Energy Information Administration).

Most of the oil consumed in the United States is used in the transportation sector, absorbing 69 percent of U.S. oil consumption in 2006. The rest is used by the residential, commercial, and industrial sectors, and for electricity generation (see Chart 7-2). The largest domestic sources of oil production are offshore wells in the Gulf of Mexico, and wells in Texas, Alaska, and California. Imported oil primarily comes from Canada, Mexico, Saudi Arabia, Venezuela, and Nigeria; and petroleum is the largest imported energy source for the United States. Because of this reliance on oil, changes in its price can affect the U.S. economy, and in 2008, the price of oil hit record levels (see Box 7-1).

### **Box 7-1: Oil Prices**

In 2008, the nominal price for crude oil reached its highest level ever. This increase was due to several economic, geopolitical, and environmental factors such as growing world demand, limited supply growth, smaller inventories, security concerns in oil producing countries, and a decline in the value of the U.S. dollar.

Some fear that high oil prices reflect a peak in oil production and predict an imminent decline in production in the near future. This type of prediction often assumes static or growing consumption with limited additional discovery or production. As the price of oil rises, however, there is an economic incentive to find new sources or improve extraction techniques. Enhanced oil recovery (EOR) is one example of this type of response. EOR is any technique that can increase the amount of oil that can be recovered from an oil field, but it is most commonly associated with gas injection, particularly using CO<sub>2</sub>, which forces the oil to the surface. The Department of Energy estimates that state-of-the-art EOR could potentially add an additional 89 billion barrels to the total recoverable oil resources of the United States, although not all of that is necessarily economically recoverable.

Even if production has peaked, we are unlikely to abruptly run out of oil. As the price rises over time, producers will have an incentive to retain some of the resource to sell at a later date and consumers will have an incentive to transition away from oil consumption. Over time, the price rise will make the adoption of alternative energy sources more and more likely.

The next largest fuel types are coal and natural gas, comprising 23 percent and 22 percent of consumption respectively. In 2006, coal production in the United States reached a record 1,161 million short tons (one short ton equals 2000 pounds), while consumption was 1,114 million short tons. This coal produced 23.8 quadrillion Btu of energy, the vast majority of which was used for electricity generation by the power sector. Coal continues to be a major fuel source for the United States largely due to its domestic abundance. The United States has 18,880 million short tons of recoverable coal reserves at producing mines and an estimated 263,781 million short tons of total recoverable reserves. Domestic coal production comes primarily from three geographical regions—Western, Interior, and Appalachian—and there is a small amount of both imported and exported coal.

In 2006, the United States consumed 21.9 trillion cubic feet (Tcf) of natural gas. By comparison, total world natural gas consumption was 105.5 Tcf, with the United States and Russia combined consuming 36 percent of the world total. U.S. natural gas consumption produced 22.4 quadrillion Btu of energy, with 69 percent used by residential, commercial, and industrial sources and 29 percent used for electricity generation. Domestic gas production comes mainly from the Gulf of Mexico and older-producing areas in Texas, Oklahoma, and Louisiana. Imports, which make up 16 percent of consumption, come mainly by pipeline from Canada.

## The Need To Diversify

For more than a century, fossil fuels have satisfied the bulk of America's demand for energy. However, a move to alternative energy sources can hold a number of benefits.

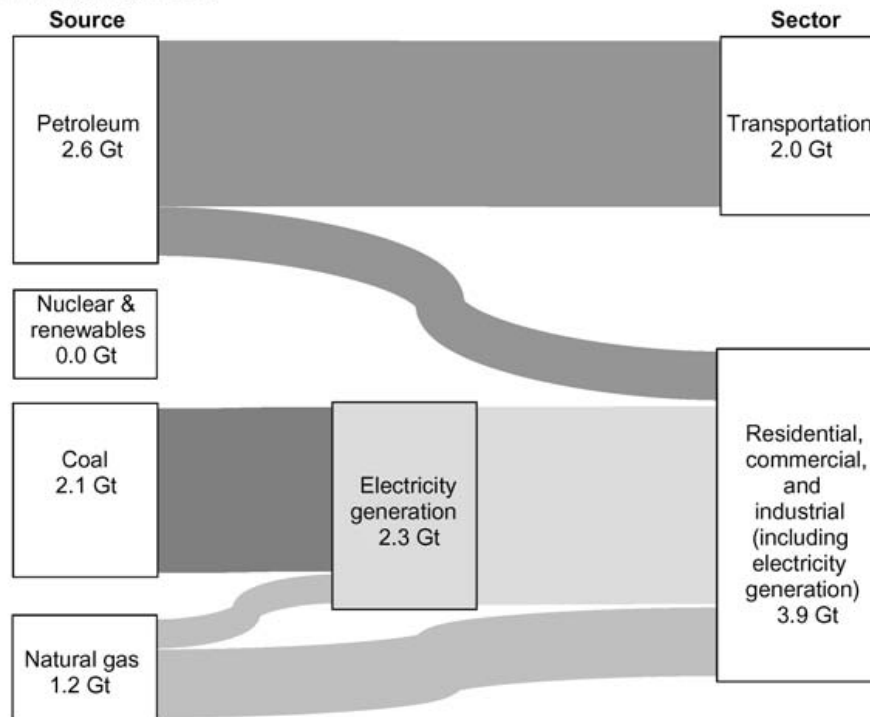
One of the reasons for shifting away from fossil fuels is improved energy security. This term can have multiple meanings, but it is often applied to the desire to reduce the Nation's vulnerability to oil supply disruptions from political or terrorist actions or natural disaster. However, because there is a world market for oil and a world price, the price of oil rises in the case of a disruption no matter the source of supply, be it foreign or domestic. Thus, energy security in this context cannot be obtained by simply shifting from one supplier to another. It requires diversifying the fuels consumed in our energy portfolio, which reduces the amount by which a disruption in any one energy source can affect the economy. In this context, alternative energy technologies for both electricity production and for transportation can dampen the impact of sharply rising prices, and thus provides an energy security benefit.

A second major benefit of alternative energy is that some alternative energy sources have a lower environmental impact than traditional fossil fuels. At the point of generation, wind, nuclear, hydropower, and solar sources produce no local air pollution, such as sulfur dioxide (SO<sub>2</sub>) and nitrogen oxides (NO<sub>x</sub>).

Also, depending on the fuel and technology used, alternative energy can reduce CO<sub>2</sub> emissions. In 2006, the United States emitted approximately 5.9 billion metric tons of energy-related CO<sub>2</sub>, almost 73 percent of which were generated by fossil fuel use for transportation and electricity generation. Approximately one-third of all energy-related CO<sub>2</sub> in the United States came from petroleum use in the transportation sector and 38 percent came from coal and natural gas used to generate electricity (see Chart 7-3). Appropriately chosen alternative energy sources in the transportation and electricity generation sectors may help reduce these emissions.

A third potential benefit of alternative energy is that some believe that it may eventually compete with or cost less than fossil fuels. It is worth noting, however, that reduced energy cost, whether achieved through improved energy efficiency or less expensive energy supply, will result in increased energy demand, a phenomenon known as the *rebound effect*. For example, the Department of Transportation sets mandatory Corporate Average Fuel Economy (CAFE) standards for passenger cars and light trucks. When fuel efficiency standards are raised, vehicles use less gasoline per mile; but, because

**Chart 7-3 U.S. CO<sub>2</sub> emissions from Energy Consumption (2006)**  
 The United States emitted 5.9 billion metric tons (Gt) of carbon dioxide from energy consumption in 2006.



Note: This chart does not depict some smaller emissions flows, including 0.2 Gt of direct emissions from coal by residential, commercial, and industrial sources; 0.3 Gt of emissions from petroleum by the electricity-generation sector; 0.03 Gt of direct emissions from natural gas by the transportation sector; and emissions from non-fuel use.  
 Source: Department of Energy (Energy Information Administration).

the increased fuel efficiency reduces the cost of driving, people drive more. This leads to less gasoline savings than implied by the change in fuel efficiency. The economic literature puts the rebound effect between 10 percent and 20 percent, which means that a 10 percent improvement in fuel efficiency would actually only produce an 8 to 9 percent improvement in energy consumption.

## Alternative Energy Production

While some of the electricity produced in the electric power sector is generated using alternative energy sources, the majority (71 percent) is generated from fossil fuels. In the transportation sector, almost all of the energy consumed comes from fossil fuels. Developing alternative energy sources in these two sectors could move us down the road to enhanced energy security and lower pollution.

### Alternatives for Generating Electricity

In the United States, electricity is generated using a wide variety of energy sources, both traditional and alternative. One factor affecting which type of electricity plant will be built at any given time is economics: which energy source will produce the greatest economic return over the lifetime of the plant. However, it is difficult to compare plants that differ in both cost and generation capacity. One way to assess this economic return is to compare the *levelized cost of electricity* (LCOE)—the present value of the total cost of building and operating a generating plant over its financial life, converted into equal payments and amortized over the expected annual generation from the plant. Table 7-1 provides the estimated national average LCOE for various types of electricity generating plants entering service in 2015. The final column of Table 7-1 gives the national average total system LCOE, while the four columns prior to the last give the components that make up this total system cost.

Conventional coal-fired power plants have an average real LCOE of approximately \$61 per megawatt hour produced, which is the lowest cost of all electricity generation methods presented. Natural-gas combined cycle plants have an average LCOE of between \$65 and \$68 per megawatt hour produced, and are closely competitive with coal-fired power plants. On an average LCOE basis, alternative energy based electricity generation is more expensive than both coal and natural gas-based plants, which partially explains their lack of penetration in the market.

The LCOE, however, is not the only consideration in choosing which type of plant to build. Because the demand for electric power varies by time of day and season and because electricity is difficult to store, plants may



TABLE 7-1. —*Estimated Average Levelized Costs  
(2006 \$/megawatthour) for Plants Entering Service in 2015*

Plant Type	Capacity Factor (%)	Levelized Capital Cost	Fixed Operations & Maintenance (O&M) Cost	Variable Operations & Maintenance Cost (including fuel)	Transmission Investment	Total System Levelized Cost
<b>Fossil Fuel Based Electricity Generation.....</b>						
<i>Coal-fired.....</i>						
Conventional Coal.....	85	\$31.4	\$3.6	\$22.3	\$3.6	\$60.9
Advanced Coal.....	85	36.9	5.1	18.4	3.5	63.9
Advanced Coal with CCS.....	85	52.0	6.0	22.3	3.5	83.8
<i>Natural Gas-fired.....</i>						
Conventional Combined Cycle.....	87	14.1	1.6	48.7	3.7	68.1
Advanced Combined Cycle.....	87	13.8	1.5	45.8	3.7	64.8
Conventional Combustion Turbine.....	30	25.7	4.5	72.5	10.8	113.4
Advanced Combustion Turbine.....	30	24.0	3.9	61.9	10.8	100.6
<b>Alternative Energy Based Electricity Generation..</b>						
Advanced Nuclear.....	90	50.7	8.4	8.2	2.5	69.7
Geothermal.....	90	47.9	20.1	0.0	4.9	72.9
Biomass.....	83	48.3	8.6	18.9	4.0	79.8
Wind.....	35	64.6	9.6	0.0	8.2	82.5
Solar Thermal.....	31.2	122.8	20.7	0.0	10.5	154.0
Solar PV.....	21.7	268.8	6.1	0.0	13.0	287.9
Conventional Hydropower.....	.....	.....	.....	.....	.....	.....

Source: Department of Energy (Energy Information Administration).

be designed to provide base load power (a constant supply of power), peak load power (when demand is the highest), or to serve as “merchant” plants, selling electricity in the commercial market when it is profitable to do so. The second column in Table 7-1 gives the average capacity factor, which is the ratio of the actual energy produced in a given period to the hypothetical maximum energy output of the plant. While natural gas combustion turbines have a lower capacity factor and a higher LCOE than other fossil fuel based plants, they are attractive as peak load or intermediate load (between base load and peak load) plants. Additionally, fuel prices vary regionally due to transportation costs and resources.

Other factors may also be important in determining what type of plant is built. For example, many states have renewable portfolio standards that require minimum additions to capacity from renewable electricity technologies and there may be tax incentives for alternative energy power generation. The values in Table 7-1 do not reflect these factors. Power producers may also consider environmental factors that could affect technology investment decisions. These considerations may depend on a regulatory environment that differs substantially in different regions of the country. Investors may be concerned that future policies could increase the cost of coal or make it more difficult to dispatch coal-fired power. Finally, LCOE

estimates are subject to additional uncertainty not discussed here. For example, actual fuel prices may differ from those assumed for the LCOE estimates. The “best” power generation technology may vary throughout the country, but the LCOE gives some indication of the relative cost of various types of electricity generating plants.

### *Nuclear Power*

There are currently 104 commercial nuclear power reactors in the United States, and they generate approximately 20 percent of the Nation’s electricity. While the United States has the largest nuclear capacity of any nation, no new commercial reactor has been ordered and approved for construction since 1978, and all of the plants ordered after 1973 have been cancelled. The last plant to come online was the Watt’s Bar reactor in Tennessee in 1996. Despite this, the total nuclear capacity per plant in the Nation has increased over time due to *uprating*, a process by which a plant is upgraded and then a more highly enriched fuel and/or a higher percentage of new fuel is used to generate more power. The Nuclear Regulatory Commission (NRC) has approved 114 power uprate proposals to date and is currently reviewing 13 additional uprate proposals, which would add an additional 1,220 megawatts of electric power. According to NRC, they could receive 24 additional applications for power uprates by 2012. However, there is a limit to our uprate potential, and more reactors will be needed if the United States chooses to get more of its electricity from nuclear power plants. To date, the NRC has received applications for 4 units and a partial application for a fifth unit, and expects to receive applications for as many as 32 units over the next three years. However, there is no requirement that a reactor be built for every license granted.

One advantage to nuclear power is that it has low operating cost, so the cost differential between limited output and full capacity is small. These plants operate at close to full capacity and provide a reliable *base load*, which is a constant supply of the electricity to power lines. Another advantage of nuclear power is that it can produce power using a relatively small amount of fuel without producing air pollutants or CO<sub>2</sub> emissions.

A few of the disadvantages to nuclear power include the length of time required to build a new plant, high capital costs, and the cost of liability insurance. In addition to these economic disadvantages, nuclear power faces a number of obstacles including social opposition to its use, partially due to fears generated from the partial meltdown of the core of the power plant at Three Mile Island in 1979 and the disaster at the Chernobyl nuclear power plant in Ukraine in 1986, as well as additional safety concerns. There is also concern about the current lack of long term storage for the radioactive waste generated that must be properly contained for centuries. In 2002, the President signed a resolution to allow for the storage of nuclear waste at Yucca Mountain in

Nevada. The facility is expected to begin accepting waste in 2017, although limits on funding the facility have in the past delayed the opening and may do so again in the future. Additionally, the Nuclear Waste Policy Act limits the amount of waste that can be stored at the facility to 63,000 metric tons of commercial spent nuclear fuel, and it is estimated that the commercial nuclear facilities currently operating in the United States will produce this much spent fuel before 2017. Unless the capacity at Yucca Mountain is increased by statute or a second site is opened, we will face challenges in storing the commercial spent nuclear fuel generated from nuclear plants.

One possible solution to the storage issue is nuclear recycling. Virtually all of today's nuclear power is generated in an "open fuel cycle" in which enriched uranium fuel is used once and then disposed of. However, only part of this fuel is actually consumed in the process and the residual still has potential energy. Spent nuclear fuel can be recycled to recover some of this remaining energy, and this is done in several nations. A second type of nuclear plant using an "advanced burner reactor" can be designed to consume the residual, producing a "closed fuel cycle" process. It is important, however, that any such recycling program be implemented in such a way so as not to produce weapons-grade nuclear material. This is the central goal of the Global Nuclear Energy Partnership (GNEP) announced by the President in the 2006 State of the Union Address.

### *Hydropower*

Hydropower, which is used almost exclusively to generate commercial electricity, is the largest renewable energy source used by the electric power sector. In 2006, the United States consumed 2.9 quadrillion Btu of conventional hydroelectric power, about 42 percent of all renewable energy consumption. The State of Washington generates the most hydropower among all states, followed by California, Oregon, and New York. Hydropower works by powering turbines with either the force of the current or the fall of water from a reservoir or dam.

The advantage of hydropower is that it is a well-understood renewable power source that can supply both peak load demand, by reserving available water for high value periods, as well as base load demand. Hydroelectric plants do not produce air emissions and there are some positive externalities associated with them because the reservoirs and dams can provide irrigation benefits, recreational opportunities, and flood control. However, hydropower also produces negative ecological effects. Hydropower's largest disadvantages are its negative impact on the surrounding environment, low dissolved oxygen in the water, impacts on the fish and the riverbank habitat, and alteration of fish migration corridors (e.g. salmon runs). Even if the environmental concerns are removed, however, there is limited ability to expand hydropower beyond what is currently available. The total U.S. hydropower capacity, including

pumped storage facilities, is about 98 gigawatts, and the Department of Energy estimates that there are only 30 gigawatts of undeveloped capacity remaining in the entire 50 states.

### *Biomass*

Biomass is organic material from plants and animals, such as wood, crops, manure, and some garbage, and is second only to hydroelectric power in providing renewable electricity to the United States. Biomass, excluding biofuels, makes up about 2.5 percent of the Nation's total energy consumption and comprises almost 37 percent of the total renewable energy consumption in the country. Sixty-four percent of this biomass is used directly by the industrial sector to generate power. Only a small portion is used by the power sector to generate electricity.

The main advantage to biomass is that it is a renewable source of energy that can be used either as a dedicated fuel to generate electricity or can be co-fired with other fossil fuels. Compared with coal, biomass produces fewer CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>x</sub> emissions. If biomass is grown specifically for electricity generation, in a closed loop system, then the only CO<sub>2</sub> emissions come from the harvesting, transportation, and processing operations.

The main disadvantage to electricity generation using biomass is that it currently has an average LCOE above generation using fossil fuels. This is due to a number of factors, including the cost of obtaining the raw material. Also, biomass energy consumption is technically not a zero-emission process.

### *Geothermal Power*

Geothermal energy is contained in underground reservoirs of steam, hot water, and hot dry rocks. Large geothermal power plants use this energy to generate electricity by drilling below the earth's surface in order to release or produce steam, which is used to power turbine generators. After the steam condenses, the water can be injected back into the ground to be used again. Geothermal energy currently makes up about 5 percent of the total renewable production of the country, but it only supplies about 0.4 percent of the Nation's electricity. It is considered an attractive resource because it requires a relatively small plant footprint, requires no storage, has no fuel costs, and can provide continuous base load power. A study by the Government Accountability Office reports that there are at least 400 undeveloped wells and hot springs with potential for future electricity production.

Geothermal power, however, is limited in its ability to provide large amounts of electricity to the country. To be viable, geothermal power requires access to permeable rock systems filled with steam or water at temperatures from 300 to 700 degrees. Sites that meet these conditions are much more prevalent on the West Coast than in other parts of the country. Also, geothermal sites can produce some local pollutants and small amounts of CO<sub>2</sub>.

## *Wind Power*

Wind power supplies about 4 percent of our renewable energy and less than 1 percent of the Nation's electricity, a small percentage compared to large wind users such as Denmark, Spain, Portugal, and Germany. However, the use of wind power in the United States is on the rise, and appears to be poised for dramatic increases in the future. In 2006, wind capacity increased by 29 percent, and the United States has led the world in capacity additions in recent years. An estimated 4 gigawatts of wind capacity were added in 2007. This growth is due to the fact that, in some areas, wind is now cost competitive with other sources of energy production, largely because of a government tax credit of 1.9 cents for each kilowatt hour produced (not reflected in Table 7-1).

Wind power is desirable because it is a domestic source of power with no fuel costs or emissions. It has become increasingly popular for two reasons. First, the current generation of windmills produces more power from a given wind resource than past technologies. The amount of electricity generated from a windmill is determined by a number of factors including the turbine size and the capacity factor. The size of the turbine dictates the potential output of the windmill, and the average turbine size has approximately doubled since 2000 to about 1.6 megawatts. The windmill's capacity factor is its actual energy output divided by its potential output. The average capacity factor has shown substantial improvement and is now roughly 35 percent. Second, windmills are increasingly popular because they can be placed on farms, providing a source of lease income, without having a large impact on the surrounding farming activity.

The ability of wind power to grow as an alternative energy source is affected by a number of factors. First, the capacity factor is very sensitive to the average wind speed and it can drop dramatically for sites with less optimal wind profiles, meaning less electricity from each windmill. Second, to maximize the market potential, wind-generated electricity must be integrated with the overall power grid, the system of power lines and transformers that distribute electricity. When wind farms are located in rural areas, some electricity is lost during the transmission to homes and businesses. In addition, since wind energy is generated only when the wind blows and the electricity cannot be economically stored at this time, wind is an intermittent energy source. Finally, there is some public opposition to wind power. Because of the height of the turbine, wind plants produce a large visual footprint, and there is a potential effect on migratory bird and bat populations.

## *Solar Power*

Solar power has captured the imagination of alternative energy advocates and lends itself to creative demonstration projects like the installation of

solar panels on the roof of the West Wing of the White House. Solar power is attractive because its output closely aligns with peak electricity demand. The fact is, though, beyond some niche markets, solar power is not yet an economically competitive method of supplying large amounts of electricity. Solar power currently comprises 1 percent of the total renewable energy production and it produces a negligible amount of the Nation's electricity. This is largely because solar power has a levelized cost of electricity above other energy sources.

Solar power generation generally comes in two forms: photovoltaic and thermal. Photovoltaic generation involves the direct conversion of light energy into electricity through the use of semiconducting material like silicon. This technology already has some commercial success for low-power devices like calculators and emergency phones, but is a relatively expensive method of producing large amounts of electricity. At present, photovoltaic generation is generally used when grid connection is difficult or impossible, such as for satellites. However, progress has been made in reducing the cost and improving the efficiency of silicon-based photovoltaic cells as well as newer, thin-film technologies. Photovoltaics can be used for distributed electricity generation at homes and businesses, and may eventually serve as an alternative to bulk power provided by the electricity sector.

Solar thermal devices use direct heat from the sun, concentrating it in some manner to produce heat. Solar power plants focus heat in troughs, dishes, or large power towers to generate electricity, in what is called "concentrating solar power" (CSP) technology. If combined with thermal storage, CSP could reduce the problem of an intermittent power supply. However, currently, CSP plants are expensive. They also require a large amount of space and are considered aesthetically unappealing by some, and thus could be sited away from population centers. This means that there would be transmission losses in moving the electricity to population centers.

### *Summary of Alternatives for Generating Electricity*

There are many alternative sources of energy for generating electricity. Some of them are more promising than others due to costs and other technological barriers. Nuclear power's LCOE is closest to coal and natural gas production and is currently best suited to produce large amounts of electricity without using fossil fuels, but it requires large and expensive plants and is often socially unpopular. Hydropower currently provides the majority of the Nation's renewable electricity production, but it is very limited in its ability to expand. Biomass, geothermal, and wind power are close to economically competitive with nuclear and fossil fuel production and have the potential for expanded use, provided that the constraints described above can be overcome. Finally, while solar power is currently an expensive way to produce large

amounts of electricity, it could be an important source of alternative energy if costs can be reduced.

## Alternatives for Transportation

Twenty-eight percent of the energy consumed by the United States is used for transportation: cars, trucks, planes, trains, and ships. Unlike the energy used to generate electricity (of which 31 percent is generated using non-fossil fuels), transportation relies almost entirely on petroleum-derived fuels. As with electricity generation, a great emphasis has been placed on finding alternative transportation fuel sources for both energy security and environmental reasons.

One solution is to find an alternative fuel to use in our cars and trucks. At present, corn-based ethanol is the largest alternative fuel source, but other fuels, like biodiesel, are also available. Our current vehicle fleet can burn a gasoline mixture containing up to 10 percent ethanol without any modification; flexible fuel vehicles are already being sold that can operate on 85 percent ethanol; and other alternative fuel vehicles, such as natural gas-powered vehicles, have long been used in niche markets. In addition, investments in second generation biofuels, like cellulosic technologies to convert non-food crop residues, grasses, and forest biomass, are on the rise.

Another alternative energy solution for transportation is to design a different type of car. Hybrid vehicles are part of the current car stock, but other advanced technologies are under development including hydrogen-powered vehicles and plug-in hybrids that would allow consumers to charge on-board batteries and achieve a limited range using electricity.

### *Corn-Based Ethanol*

*Ethanol* is a fuel made from grains and biomass that can be used as a gasoline supplement for automobiles. By far, the most common raw material or *feedstock* used to produce ethanol in the United States is corn. Since 1978 major manufacturers of fuel tanks have provided the same warranties for use of both unblended gasoline and ethanol blends up to E10 (10 percent ethanol and 90 percent gasoline). Flex-fuel vehicles (FFVs) can use blends containing more than 10 percent ethanol, such as E85, and auto manufacturers can produce FFVs at only a small additional cost. In 2007, of a total 229 million light-duty cars and trucks on the road, an estimated 5.5 million were FFVs, and this portion will likely grow. It is estimated that by 2030, approximately 10 percent of the total U.S. car and truck sales will be FFVs. However, of approximately 170,000 fueling stations in the United States, only 1,183 offer E85, so flex-fuel vehicles have a harder time locating stations offering this fuel.

Ethanol has a number of advantages over oil. First, it is domestically produced, so its use decreases the impact from a disruption in the oil market.

Second, the production of ethanol releases less carbon monoxide emissions (but can increase other pollutants such as nitrogen oxides and non-exhaust volatile organic hydrocarbon) than gasoline use. Finally, depending on how it is produced, ethanol may reduce CO<sub>2</sub> emissions.

Since January 1999, annual ethanol production has increased more than 300 percent, from 1.5 billion gallons to an estimated 6.3 billion gallons in 2007. Including new and expanding plants, one industry group estimates that the United States may soon have the capacity to produce more than 13 billion gallons of ethanol annually. Four major factors have driven the dramatic growth in this market. First, high oil prices have increased the demand for an alternative fuel. While ethanol has one-third less energy content than gasoline, oil prices are high enough for ethanol to compete with gas on an energy-equivalent basis. However, as oil and ethanol prices move, so will the significance of this factor. Second, the elimination of MTBE—a gasoline additive used to produce cleaner fuel in cities with smog problems that was found to contaminate groundwater—has increased the demand for ethanol as a substitute oxygenating agent. Third, there are financial incentives for ethanol production. There is a 51-cent per gallon Federal tax credit for blending ethanol into gasoline (and an associated 54-cent per gallon tariff on imported ethanol) and additional subsidization in some states. Finally, the Energy Policy Act of 2005 mandated the use of 7.5 billion gallons of renewable fuel by 2012, much of which was expected to be met with ethanol. The recently passed Energy Independence and Security Act of 2007 increases this mandate to 36 billion gallons of renewable fuel by 2022, which will likely increase the demand for ethanol.

There are a number of concerns about ethanol. First, some worry that production will outstrip the capacity to blend ethanol into the gasoline supply. (See Box 7-2) Second, the current oil pipeline infrastructure is not capable of transporting ethanol, so it must be shipped by truck, train, and barge. To remain cost competitive, ethanol plants are generally located within 50 miles of where the corn is grown. Ninety percent of the productive capacity is in eight Midwestern States while 80 percent of the U.S. population (and thus, the ethanol demand) lives along the coastline. Rail transport capacity from the Midwest to the coasts is limited, and dedicated ethanol barges (to move ethanol from the Midwest to the Gulf Coast) will take time and money to construct. Third, there are environmental concerns about ethanol production depleting groundwater aquifers and water pollution from fertilizers used to grow crops for biofuels. Finally, there are fiscal concerns, particularly the cost of the 51-cent per gallon blender's credit.

The growing demand for corn-based ethanol as fuel is affecting the overall corn market. Most of the adjustment will take place over the next couple of



years, as corn-based ethanol production responds to market signals. Over time, other markets will adjust to higher corn demand, and ethanol substitutes will come online. The Department of Agriculture estimates that acres of planted corn increased to 93.6 million in marketing year 2007/08 and corn production increased to 13.1 billion bushels, an increase of almost 24 percent from marketing year 2006/07. Corn prices are also projected to rise to as much as \$3.75 per bushel by 2009/2010 before stabilizing, and the U.S. share of global corn trade is projected to fall to less than 60 percent.

Increased production of ethanol will also affect other crops, particularly soybeans because it competes with corn for cropland. Land devoted to soybeans is expected to decrease from 71 million acres now to 69 million acres by 2009/2010, and the price of soybeans is expected to rise from \$5.66 per bushel in 2005 to \$7.30 by 2009/2010 before stabilizing. Livestock production will also face higher costs as grain prices rise and the price of its final product (meat, eggs, and milk) will follow. Corn farmers will obtain higher

### **Box 7-2: The Blend Wall**

In the United States, nearly all of the ethanol produced is blended into E10 fuel. In 2005, nearly 4 billion gallons of ethanol were blended into 137 billion gallons of gasoline. By 2007, ethanol production is estimated to have grown to 6.3 billion gallons, and the total capacity could eventually reach 13 billion gallons per year. Some worry that production will ultimately outstrip the capacity to blend ethanol into E10. (By definition, ethanol cannot exceed 10 percent of the gasoline pool if it is blended exclusively into E10.) This limit to the use of ethanol (basically, where ethanol supply exceeds demand) is referred to as a “blend wall.”

There are a number of reasons why the blend wall is unlikely to pose a significant problem. The United States consumes around 140 billion gallons of gasoline per year, meaning that almost 14 billion gallons of ethanol can be used for E10 alone. In addition, if all existing FFVs used E85, they would consume an additional 3.5 billion gallons of ethanol. Therefore, the total potential demand for ethanol blending is currently around 17.5 billion gallons, and this amount will grow as more FFVs are produced. Even extrapolating the rapid growth in ethanol production, potential demand is well above the production capacity. As the supply of ethanol grows (reducing the price of ethanol) or as the price of oil rises, ethanol looks increasingly attractive compared to oil, and more trucks and rail cars will be devoted to distribution and more E85 pumps will be installed in order to capture the profits of an economically valuable commodity.

prices for their products, but livestock producers will face higher production costs; and government counter-cyclical payments and market loans will likely decrease due to higher commodity prices. On net, however, it is likely farm incomes will rise as consumer prices rise.

### *Cellulosic Ethanol*

Cellulosic ethanol is similar to corn-based ethanol, but it can be produced from a variety of biomass feedstocks such as agricultural plant wastes, industrial plant wastes (such as sawdust and wood pulp), and crops grown specifically for fuel production (such as switchgrass). Because cellulosic ethanol can come from a variety of raw materials, it can be produced in nearly every region of the country and has the potential to supply more fuel per acre than corn. Cellulosic ethanol production also produces less greenhouse gas (CO<sub>2</sub>, methane, and nitrous oxide) emissions than either gasoline or corn-based ethanol.

While clearly desirable from both an energy security and an environmental perspective, cellulosic ethanol is not yet commercially available because the conversion technology is only in its introductory stages and is expensive. There are currently no commercial cellulosic ethanol refineries in operation in the United States, but the Department of Energy has announced that it will invest \$385 million over the next four years in a cost-sharing program with private companies to fund six biorefinery projects located in California, Georgia, Florida, Kansas, Idaho, and Iowa. By 2012, these refineries are expected to produce 130 million gallons of cellulosic ethanol each year at less than \$2 a gallon.

### *Biodiesel*

*Biodiesel* is a renewable fuel that can be made by chemically combining natural oils and fats with an alcohol. It can be used by vehicles that use diesel fuel, and it is typically blended with petroleum diesel at levels up to 20 percent. Most U.S. biodiesel is made from either soybeans or yellow grease from restaurant cooking oil. Like ethanol, biodiesel is a domestically produced fuel and, depending on how it is produced, its use generates about two-thirds less greenhouse gas emissions than petroleum-based diesel. At present, however, it is economically viable only because of a \$1 per gallon tax credit for blending biodiesel from virgin oil (oil in its first-use) and a \$0.50 per gallon credit for blending with recycled oil.

### *Alternative Vehicles*

An alternative to developing new fuels is to develop a different type of car that uses less gasoline. Two such vehicles currently exist. Conventional hybrid vehicles combine the internal combustion engine of a standard vehicle with the battery and electric motor of an electric vehicle. This gives them

the power, range, and convenient fueling of conventional vehicles, but lower emissions and better gas mileage. Hybrid passenger cars first became available in the United States in 2000 and have gained an increasing share of the U.S. car market, growing to 2.1 percent of the U.S. car sales in 2007. Part of this is due to a tax credit introduced in 2006 for purchasing a hybrid vehicle. This credit of up to \$3,400 varies by model and is based on both the lifetime fuel savings and the fuel efficiency of the car measured against a 2002 baseline. However, in order to limit cost to the taxpayer while providing incentive to multiple automakers, this tax credit is phased out for each car manufacturer once it has sold over 60,000 eligible vehicles. A number of manufacturers have already reached this limit.

A second type of alternative vehicle is one powered by natural gas. Though major auto makers sell natural gas-powered cars in Europe, Asia, and South America, they have not sold well in the United States. There are about 150,000 natural gas vehicles in the United States (compared to 5 million worldwide), most of which belong to corporate or government fleets. The low demand for these vehicles is due, in part, to a shorter driving range, smaller trunks due to larger fuel tanks, and a lack of retail stations selling natural gas. However, increased use of natural gas-powered vehicles could both provide both greater fuel diversity and lower CO<sub>2</sub> emissions.

### *Plug-in Hybrids*

Plug-in hybrid cars are a different type of vehicle that has the potential to both improve energy security and decrease pollution. Unlike conventional hybrids, which only recharge the electric battery through braking recovery, a plug-in hybrid is also charged with electricity delivered to the home or business. As a consequence, the vehicle can displace gasoline consumption with electricity that it draws from the grid. Some models under development would run on electricity for about 40 miles. Since 50 percent of personal automobiles travel 20 miles or less daily, plug-in hybrids may consume substantially less gasoline than a conventional hybrid. A recent study suggests that if plug-in hybrids were to be widely adopted and powered with low-carbon generated electricity, they could mitigate a large portion of the Nation's CO<sub>2</sub> emissions from transportation.

The major hurdle to the commercialization of the plug-in hybrid vehicle is the battery. Technology barriers include the battery cost, size and weight, power density, durability, reliability, and safety. With continued improvements, however, plug-in hybrids could eventually become commercially feasible.

### *Hydrogen-Based Fuel Cell Vehicles*

Hydrogen can be used as a fuel with its chemical energy converted to electricity in a fuel cell. Pressurized hydrogen gas is forced through a catalyst and is split into positively charged hydrogen ions and electrons. The hydrogen

ions are combined with oxygen to form water and the electrons are used to generate electricity.

There are many possible uses of fuel cells, including primary electricity generation from stationary fuel cells, as well as hydrogen-based fuel cell vehicles. In a fuel cell vehicle, a series of fuel cells generate electricity to power the car's electric motor, and there is no exhaust other than water vapor. Since hydrogen can be produced domestically, fuel cells could provide domestically-fueled vehicles that produce no CO<sub>2</sub> or other harmful emissions from the tailpipe.

While hydrogen has great potential as an alternative fuel, it does face some limitations. Currently, it is more expensive than other energy sources. Production, storage, and delivery are the largest cost categories associated with hydrogen-based energy. Hydrogen can be produced in small quantities where it is needed, such as at a vehicle refueling station, but the production cost can be high. In contrast, larger, centralized facilities can produce hydrogen at a lower cost, but the delivery costs are high. Additionally, the full infrastructure has not been built to accommodate hydrogen fuel, and there are safety concerns with hydrogen pipelines and dispensing systems.

### *Summary of Alternatives for Transportation*

While the United States currently blends corn-based ethanol, the transportation sector still depends on petroleum as its primary energy source. Changes to either the fuel we use or the vehicles themselves will be necessary if we are to substantially reduce this dependency. On the fuel side, we can reduce our reliance on oil by developing alternative fuel like cellulosic ethanol and biodiesel. On the vehicle side, we can develop vehicles that simply do not require gasoline, such as plug-in hybrids or hydrogen-fueled vehicles. Done carefully, these measures will not only enhance energy security but could also reduce CO<sub>2</sub> emissions.

## The Road Forward

What we do over the next few years will dictate how quickly we can move away from fossil fuel consumption. The Energy Information Administration projects that, absent any additional action, primary energy consumption in the United States will increase 24 percent to 123.8 quadrillion Btu by 2030, an average annual increase of 0.9 percent per year. Total consumption of coal is projected to grow from 1,114 short tons in 2006 to 1,682 short tons in 2030. Natural gas is expected to increase from 21.8 trillion cubic feet in 2006 to 23.4 trillion cubic feet in 2030. Total consumption of liquid fuels and

other petroleum products is projected to grow from 20.7 million barrels per day in 2006 to 24.9 million barrels per day in 2030. Total electricity sales are projected to grow from 3,821 billion kilowatt hours in 2006 to 5,149 billion kilowatt hours in 2030, an average annual increase of 1.3 percent.

Some alternative energy will enter the market as a result of market prices, and as the market fluctuates there will be additional economic incentives to diversify our energy portfolio. If research and development leads to lower renewable energy prices, then sources such as wind power and geothermal energy may eventually become fully cost competitive. Fuel efficiency is expected to increase not only as a result of an increase in the Corporate Average Fuel Economy standards, but also due to price-driven consumer demand and the introduction of more advanced vehicles into the market. Combined total consumption of marketed renewable fuels (including ethanol for gasoline blending) is projected to grow from 6.8 quadrillion Btu in 2006 to 11.5 quadrillion Btu in 2030, with ethanol consumption growing especially rapidly. However, for alternative energy to dramatically penetrate the market, technological and other hurdles must be overcome.

## Policy Tools

There are a number of policy tools available to any administration interested in promoting alternative energy and enhancing energy security. The traditional approach is to use research and development grants to subsidize the development of new technologies that are then adopted by the private sector. An alternative is to establish a mandate, through legislation or regulation, and require the private sector to meet it. While both approaches may be useful for advancing the adoption of alternative energy, some worry that these approaches dictate which technology must be adopted. Also, while mandates do not involve direct government expenditure, they are not free. Consumers may have to pay higher prices for some alternative energy in order for the United States to receive the energy security and environmental benefits.

Another approach is to try to overcome the cost gap between conventional and more expensive alternative sources. This can be done through either tax credits or subsidies equal to the cost differential between the two technologies. In either case, there is a public cost either directly through the subsidy or indirectly through the revenue loss on allowed credits. Loan guarantees are another possible tool that can encourage investment by shifting risk to the government, but at the price of some moral hazard: if the government assumes too much of the financial risk, investors may take on highly speculative projects that have little hope of success, shifting the cost onto the Federal taxpayers.

Market-based mechanisms such as cap-and-trade and Pigovian taxes are another possible way to encourage the switch to alternative energy, provided that these programs are workable and can meet the desired objective. Cap-and-trade programs dictate the total permissible emissions or total input desired (the cap) and allow companies to trade the right to make those emissions or produce those quantities (the trade). Trading assures that the desired outcome will be achieved at the lowest cost. For example, the Renewable Fuels Standard (RFS) set in 2005 required that 7.5 billion gallons of gasoline be replaced with renewable fuel by 2012. Obligated parties were to demonstrate compliance with the program by acquiring credits (called renewable identification numbers (*RINs*)) representing the amount of renewable fuel blended into conventional gasoline or used in its neat (unblended) form. Under the trading program, however, obligated parties could purchase these credits from other obligated parties rather than acquire them themselves.

An alternative approach is to set a fixed fee (sometimes called a *Pigovian tax*) for each unit of the traded good. This is theoretically equivalent to a cap-and-trade program when the costs and benefits of the program are known. A hybrid approach is a cap-and-trade program with a *safety valve*, in which the trading of credits occurs normally, but obligated parties can choose to pay a fee (the safety valve) to demonstrate compliance rather than trading. In 2007, the President proposed that the 2005 RFS be increased to 35 billion by 2017, but proposed an automatic safety valve to protect against unforeseen increases in the prices of alternative fuels or their feedstock.

One final policy tool that has shown occasional promise is the use of inducement prizes. When a specific goal is known, the government may choose to award a prize for successfully reaching this goal as a way to spur technological innovation. For example, the government could offer a prize for overcoming the technical barriers associated with the commercialization of hydrogen and fuel cells. Prizes are desirable because they focus on rewarding the actual achievement of the goal using whatever technology gets to the solution first, whereas subsidies, grants, and contracts might only be dispersed to existing technology.

## Current Efforts

Diversifying our energy sources and fuels will not come quickly or cheaply and may require incentives for some of the alternative energy options discussed in this chapter. Over the past several years, there have been a number of successful programs promoting alternative energy. In 2006, the President announced his Advanced Energy Initiative, which called for a 22 percent increase in funding for clean-energy research and a significant reduction in our oil imports over time.

To help meet the growing demand for base load electricity generation, there are a number of programs aimed at expanding nuclear energy. The Nuclear Power 2010 program is a joint government and industry effort to develop advanced nuclear plant technology and reduce the technical, regulatory and institutional barriers to the deployment of new nuclear power plants. The United States is also part of two broad international efforts related to the development of nuclear power. The Generation IV International Forum is a cooperative effort to develop competitively priced nuclear energy systems that address nuclear safety, waste, proliferation, and public perception concerns. The goal is to have these systems available for international deployment by 2030. The Global Nuclear Energy Partnership is a group of nineteen countries that seek to expand the use of nuclear energy for peaceful purposes through a proliferation-resistant closed nuclear fuel cycle. Under this program, nations with secure, advanced nuclear capabilities would provide fresh fuel and reprocessing services to other nations who agree to employ nuclear energy for power generation purposes only.

Other efforts are aimed at improving electricity generation from renewable sources. The Department of Energy's Wind Energy Program is focused on the development of technology to make wind power cost-competitive in various areas of the country and to help reduce the barriers to electric grid interconnections. The goal of the Solar America Initiative is to make solar energy cost-competitive with conventional forms of electricity by 2015.

Finally, the recently passed Energy Independence and Security Act of 2007 takes a significant step in the direction of implementing the President's Twenty in Ten plan, which was aimed at reducing domestic gasoline consumption by 20 percent in 10 years. Under this Act, mandatory fuel standards require the production of 36 billion gallons of renewable and alternative fuels by 2022. Also, the Corporate Average Fuel Economy standards will be raised to 35 miles per gallon by 2020, a 40 percent increase from the present level. Because fuel economy standards reduce oil consumption directly (including the rebound effect) and renewable fuels are produced domestically and may generate less CO<sub>2</sub> than oil, both of these measures produce energy security and environmental benefits.

## Conclusion

Both energy security and environmental concerns motivate the consideration of policies that move toward alternative energy sources. Currently, 85 percent of our energy consumption comes from fossil fuels, and energy consumption is projected to increase 24 percent by 2030. This means that the incentive to find alternative energy solutions is growing.

Fortunately, some solutions exist. With regard to electricity generation, nuclear power is close to cost competitive and could contribute a larger share to our Nation's energy portfolio. Even though there are some constraints on their use, we should utilize our biomass, geothermal, and wind energy potential where it is economically viable. On the horizon, technological advances and cost reductions might bring in solar power. With regard to transportation, corn-based ethanol and other alternatives already reduce our gasoline consumption. The introduction of cellulosic ethanol in the next few years could reduce it further. In the longer term, introducing new vehicles like plug-in hybrids and hydrogen-based fuel cell cars could dramatically reduce our oil consumption. While none of these solutions can resolve fully our energy security and environmental concerns, together, they provide a potential portfolio of solutions to our search for alternative energy.