



C H A P T E R 9

TRANSFORMING THE ENERGY SECTOR AND ADDRESSING CLIMATE CHANGE

The President has called climate change “one of the defining challenges of our time.” If steps are not taken to reduce atmospheric concentrations of carbon dioxide (CO₂) and other greenhouse gases, scientists project that the world could face a significant increase in the global average surface temperature. Projections indicate that CO₂ concentrations may double from pre-industrial levels as early as 2050, and that the higher concentrations are associated with a likely long-run temperature increase of 2 to 4.5 °C (3.6 to 8.1 °F). With temperatures at that level, climate change will lead to a range of negative impacts, including increased mortality rates, reduced agricultural yields in many parts of the world, and rising sea levels that could inundate low-lying coastal areas.

The planet has not experienced such rapid warming on a global scale in many thousands of years, and never as a result of emissions from human activity. By far the largest contribution to this warming comes from carbon-intensive fossil fuels, which the world depends on for cooking, heating and cooling homes and offices, transportation, generating electricity, and manufacturing products such as cement and steel.

The potential for significant damages if emissions from these activities are not curbed makes it crucial for the world to transform the energy sector. This transformation will entail developing entirely new industries and making major changes in the way energy is produced, distributed, and used. New technologies will be developed and new jobs created. The United States can play a leadership role in these efforts and become a world leader in clean energy technologies. The transformation to a clean energy economy will also reduce our Nation’s dependence on oil and improve national security, and could reduce other pollutants in addition to greenhouse gases.

As this transformation unfolds, two market failures provide a motivation for government policy. First, greenhouse gas emissions are a

classic example of a negative externality. As emitters of greenhouse gases contribute to climate change, they impose costs on others that are not taken into account when making decisions about how to produce and consume energy-intensive goods. Second, the development of new technologies has positive externalities. As discussed in Chapter 10, the developers of new technologies generally capture much less than the full benefit of their ideas to consumers, firms, and future innovators, and thus underinvest in research and development.

This diagnosis of the market failures underlying climate change provides clear guidance about the role of policy in the area. First, policy should take steps to ensure that the market provides the correct signals to greenhouse gas emitters about the full cost of their emissions. Second, policy should actively promote the development of new technologies. One way to accomplish these goals is through a market-based approach to reducing greenhouse gases combined with government incentives to promote research and development of new clean energy technologies. Once policy has ensured that markets are providing the correct signals and incentives, the operation of market forces can find the most effective and efficient paths to the clean energy economy. The Administration's policies in this area are guided by these principles.

GREENHOUSE GAS EMISSIONS, CLIMATE, AND ECONOMIC WELL-BEING

The world's dependence on carbon-intensive fuels is projected to continue to increase global average temperature as greenhouse gas emissions build in the atmosphere. These emissions are particularly problematic because many are long-lived: for instance, it will take a century for slightly more than half of the carbon dioxide now in the atmosphere to be naturally removed. The atmospheric buildup of greenhouse gases since the start of the industrial revolution has already raised average global temperature by roughly 0.8 °C (1.4 °F). If the concentrations of all greenhouse gases and aerosols resulting from human activity could somehow be kept constant at current levels, the temperature would still go up about another 0.4 °C (0.7 °F) by the end of the century. It is important to note that the overall impact of today's emissions would be even higher were it not for the offsetting net cooling effect of increases in atmospheric aerosols such as particulate matter caused by the incomplete combustion of fossil fuels in coal-fired power plants.

But keeping atmospheric concentrations constant at today's level is virtually impossible. Any additional greenhouse gas emissions contribute

to atmospheric concentrations. And because of projected economic growth, particularly in developing countries, greenhouse gas emissions will continue to grow. Moreover, the sources of atmospheric aerosols that have partly offset the greenhouse warming experienced so far are not likely to grow apace because governments around the world are taking actions to curb these emissions to improve public health and control acid rain.

Greenhouse Gases

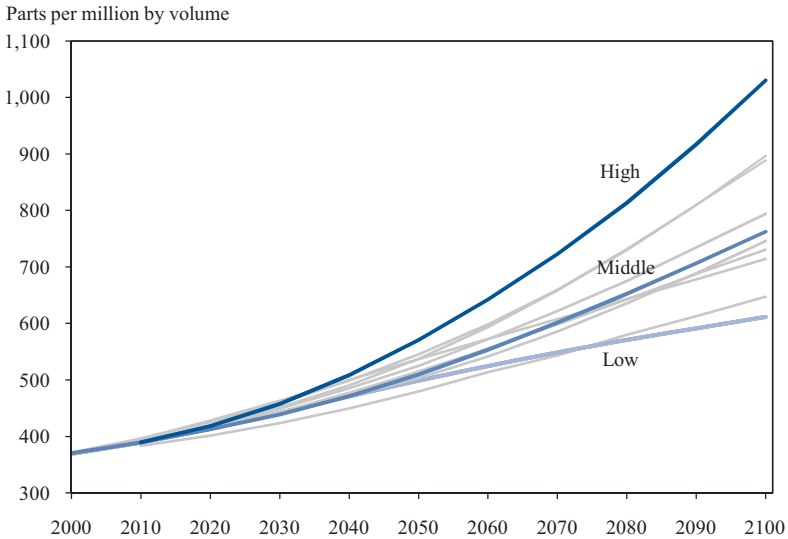
The principal long-lived greenhouse gases whose concentrations have been affected by human activity are carbon dioxide, methane, nitrous oxide, and halocarbons. Sulfur hexafluoride, though emitted in smaller quantities, is also a very potent greenhouse gas. All have increased significantly from pre-industrial levels. Carbon dioxide is emitted when fossil fuel is burned to heat and cool homes, fuel vehicles, and manufacture products such as cement and steel. Deforestation also releases carbon dioxide stored in trees and soil. The primary sources of methane and nitrous oxide are agricultural practices, natural gas use, and landfills. Halocarbons originate from refrigeration and industrial processes, while sulfur hexafluoride emissions mainly stem from electrical and industrial applications.

The pre-industrial atmospheric concentration of carbon dioxide was about 280 parts per million (ppm), meaning that 280 out of every million molecules of gas in the atmosphere were carbon dioxide. As of December 2009, its concentration had increased to about 387 ppm. Taking into account other long-lived greenhouse gases would result in a higher warming potential, but the net cooling effect of aerosols that have been added by humans to the atmosphere nearly cancels the effect of those other gases. Thus, the overall effect of human activity on the atmosphere to date is (coincidentally) about the same as that of the carbon dioxide increase alone.

A variety of models project that, absent climate policy, atmospheric concentrations of carbon dioxide will continue to grow, reaching levels ranging from 610 to 1030 ppm by 2100 (Figure 9-1). When the warming effects of other long-lived greenhouse gases are included, this range is equivalent to 830 to 1530 ppm. The breadth of the range reflects uncertainty about future energy supply, energy demand, and the future behavior of the carbon cycle.¹

¹ Underlying uncertainty about future energy supply is uncertainty regarding the costs and penetration rates of technology, and resource availability. Uncertainty about future energy demand is driven by uncertainty regarding growth in population, gross domestic product, and energy efficiency.

Figure 9-1
Projected Global Carbon Dioxide Concentrations with No Additional Action



Note: The figure shows baseline projections from 10 different models, with the models that produce the highest, middle, and lowest atmospheric concentration of carbon dioxide in 2100 noted.

Source: Stanford Energy Modeling Forum, EMF 22 International Scenarios, 2009.

Temperature Change

The implications of large increases in greenhouse gas concentrations for temperature change are quite serious. There is a consensus among scientists that a doubling of CO₂ concentrations (or any equivalent combination of greenhouse gases) above the pre-industrial level of 280 ppm is likely to increase global average surface temperature by 2 to 4.5 °C (3.6 to 8.1 °F), with a best estimate of about 3 °C (5.4 °F).² Given much higher projections of greenhouse gas concentrations by the end of the century, a recent study projects that the global average temperature in 2100 is likely to be 4.2 to 8.1 °C (7.6 to 14.6 °F) above pre-industrial levels, absent effective policies to reduce emissions (Webster et al. 2009).

Increases in global average temperature mask variability by region. For instance, absent effective policy to reduce greenhouse gas emissions, mid-continent temperature increases are likely to be about 30 to 60 percent higher than the global average, while increases in parts of the far North (for instance, parts of Alaska, northern Canada, and Russia) are expected to be double the global average. The power of the strongest hurricanes and

² These values express what is likely to happen in equilibrium. Average surface temperature does not reach a new equilibrium for some decades after any given increase in the concentration of heat-trapping gases because of the large thermal inertia of the oceans.

typhoons is likely to grow, as are the frequency and intensity of extreme weather events such as heat waves, heavy precipitation, floods, and droughts. One study, for example, estimates that the number of days that mean temperature (calculated as the average of the daily minimum and daily maximum) in the United States will exceed 90 °F will increase from about one day a year between 1968 and 2002 to over 20 days a year by the end of the century (Deschênes and Greenstone 2008).

As the increase in global average temperature warms seawater and expands its volume, sea levels are projected to rise. Melting glaciers also contribute to sea-level rise. Sea level has already risen about 0.6 feet since 1900; it is projected to rise another 0.6 to 1.9 feet because of volume expansion and glacial melt by the end of the century. These estimates exclude possible rapid ice loss from the Greenland and Antarctic ice sheets, events that are highly uncertain but that could cause another 2 feet or more of sea level rise by 2100. Without expensive adaptation, low-lying land in coastal areas around the world could become permanently flooded as a result.

Impact on Economic Well-Being

Although predicting future economic impacts associated with increases in global average temperature involves a large degree of uncertainty, these economic effects are likely to be significant and largely negative, and to vary substantially by region. Even for countries that may be less vulnerable, large negative economic impacts in other regions will inevitably jeopardize their security and well-being. For instance, the temperature extremes and other changes in climate patterns associated with global average temperature increases of 2 °C (3.6 °F) or more are projected to increase mortality rates and reduce agricultural productivity in many regions, threaten the health and sustainability of many ecosystems, and necessitate expensive measures to adapt to these changes. Box 9-1 discusses recent research on projected physical and economic impacts in the United States.

Some regions of the world are expected to be particularly hard-hit. For example, low-lying and island countries are especially vulnerable to sea-level rise. Further, developing countries, especially those outside moderate temperature zones, may be especially poorly equipped to confront temperature changes. Recent research, for example, suggests that India may experience substantial declines in agricultural yields and increases in mortality rates (Guiteras 2009; Burgess et al. 2009).

These projected changes are predicated on likely increases in global mean temperature. Particularly worrisome is the possibility of much greater temperature change, should more extreme projections prove accurate. Although more drastic increases are less likely, their consequences could be

devastating. For example, the costs of climate change are expected to grow nonlinearly (that is, more rapidly) as temperatures rise (Box 9-2).

In the United States, continued reliance on petroleum-based fuels poses challenges that go beyond climate change. It makes the economy susceptible to potentially costly spikes in crude oil prices and imposes significant national security costs. A panel of retired senior military officers and national security experts concluded that unabated climate change may act as a “threat multiplier” to foment further instability in some of the world’s most unstable regions (CNA Corporation 2007). Fossil fuel consumption is also associated with other forms of pollution that harm human health, such as particulate, sulfur dioxide, and mercury emissions from coal-powered electricity generation.

Box 9-1: Climate Change in the United States and Potential Impacts

The average temperature in the United States has risen more than 1 °C (2 °F) over the past 50 years. However, this increase masks considerable regional variation. For instance, the temperature increase in Alaska has been more than twice the U.S. average. By the end of the century, the United Nations Intergovernmental Panel on Climate Change projects that average continental U.S. temperatures will increase by another 1.5 to 4.5 °C (about 2.7 to 8.1 °F) absent climate policy (Intergovernmental Panel on Climate Change 2007). Greater increases are possible, depending in part on how fast emissions rise over time. Climate change will likely bring substantial changes to water resources, energy supply, transportation, agriculture, ecosystems, and public health. Potential effects on U.S. water availability and agriculture are described below (Karl, Melillo, and Peterson 2009).

Precipitation already has increased an average of 5 percent over the past 50 years, with increases of up to 25 percent in parts of the Northeast and Midwest and decreases of up to 20 percent in parts of the Southeast. In the future, these trends will likely be amplified. The amount of rain falling in the heaviest downpours has increased an average of 20 percent over the past century, a trend that is expected to continue. In addition, Atlantic hurricanes and the strongest cold-season storms in the North are likely to become more powerful. In recent decades, the West has seen more droughts, greater wildfire frequency, and a longer fire season. Increases in temperature and reductions in rainfall frequency will likely exacerbate future droughts and wildfires.

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Box 9-1, continued

Although warmer temperatures may extend the growing season in the United States for many crops, large increases in temperature also may harm growth and yields. One study finds that yields are relatively unaffected by changes in mean temperature, but that they are vulnerable to an increase in the number of very hot days (Schlenker and Roberts 2009). That said, another study finds that expected changes in temperature in the United States will have a relatively small impact on overall agricultural profits (Deschênes and Greenstone 2007). Neither study accounts for the possible increase in yields from elevated carbon dioxide levels or the possible decrease in yields from increased pests, weeds, and disease.

Climate change is also likely to bring increased weather uncertainty. Extreme weather events—droughts and downpours—may have catastrophic effects on crops in some years. Growing crops in warmer climates requires more water, which will be particularly challenging in regions such as the Southeast that will likely face decreased water availability.

American farmers have substantial capacity for innovation and are already taking steps to adapt to climate change. For instance, they are changing planting dates and adopting crop varieties with greater resistance to heat or drought. They can also undertake more elaborate change. In areas projected to become hotter and drier, some farmers have returned to dryland farming (instead of irrigation) to help the soil absorb more moisture from the rain. How well the private sector can adapt to the effects of climate change and at what cost is still an open question.

Box 9-2: Expected Consumption Loss Associated with Temperature Increase

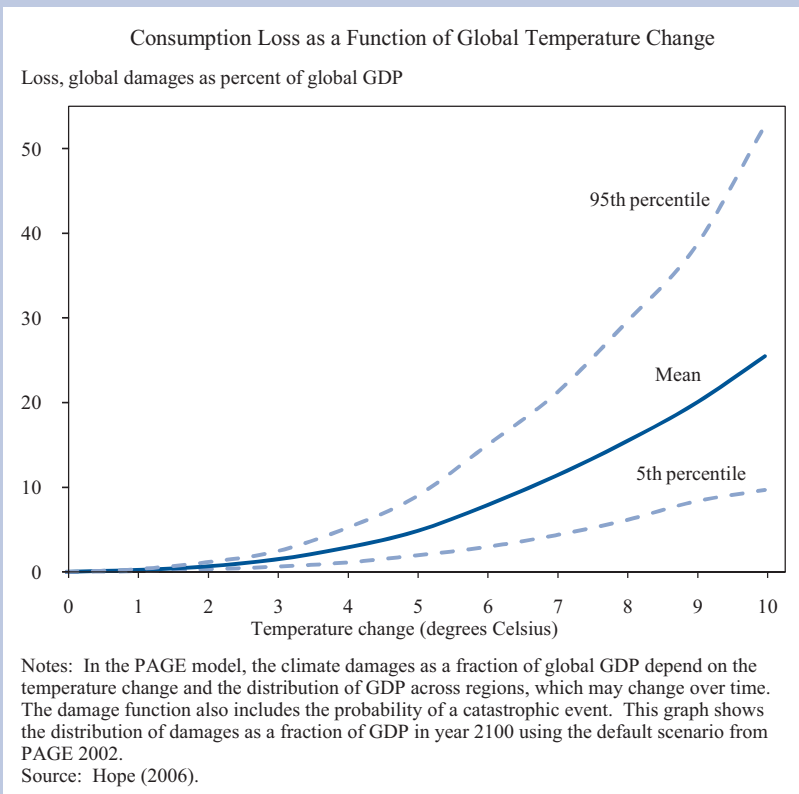
One major uncertainty regarding climate change is the relationship between temperature change and living standards, usually measured as total consumption. The highly respected PAGE model produces an estimate of this relationship (see Box 9-2 figure). Specifically, it reports the expected decline in consumption as a fraction of GDP in the year 2100. The range of these estimates is represented by the dotted lines that represent the 5th and 95th percentile of the damage estimates. The range reflects uncertainty about the sensitivity of the climate system to increased greenhouse gas concentrations, the probability of catastrophic events, and several other factors.

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Box 9-2, continued

The figure reveals that the projected losses for the most likely range of temperature changes are relatively modest. For example, at the Intergovernmental Panel on Climate Change's most likely temperature increase of 3 °C for a doubling of CO₂ concentration (concentrations in 2100 are likely to be higher), the projected decline is 1.5 percent of GDP.

The projected relationship between temperature changes and consumption losses is nonlinear—that is, the projected losses grow more rapidly as temperature increases. For example, while the projected loss for the first 3 °C is 1.5 percent, the loss at 6 °C is five times higher. And the estimated loss associated with an increase of 9 °C is about 20 percent with a 90 percent confidence interval of 8 to 38 percent. These large losses at higher temperatures reflect the increased probability of especially harmful events, such as large-scale changes in ice sheets or vegetation, or releases of methane from thawing permafrost and warming oceans. Overall, it is evident that policy based on the most likely outcomes may not adequately protect society because such estimates fail to reflect the harms at higher temperatures.



JUMP-STARTING THE TRANSITION TO CLEAN ENERGY

To make the transition to a clean energy economy, the United States and the rest of the world need to reduce their reliance on carbon-intensive fossil fuels. The American Reinvestment and Recovery Act of 2009 provides a jump-start to this transition by providing about \$60 billion in direct spending and \$30 billion in tax credits (Council of Economic Advisers 2010). These Recovery Act investments were carefully chosen and provide a soup-to-nuts approach across a spectrum of energy-related activities, ranging from taking advantage of existing opportunities to improve energy efficiency to investing in innovative high-technology solutions that are currently little more than ideas. These investments will help create a new generation of jobs, reduce dependence on oil, enhance national security, and protect the world from the dangers of climate change. Ultimately, the investments will put the United States on a path to becoming a global leader in clean energy.

Recovery Act Investments in Clean Energy

A market-based approach to reducing greenhouse gases (discussed in detail later) will provide incentives for research and development (R&D) into new clean energy technologies as firms search for ever cheaper ways to address the negative externality associated with their emissions. However, as already described, there is a separate externality in the area of R&D. Because it is difficult for the person or firm doing research to capture all of the returns, the private market supplies too little R&D—particularly for more basic forms of R&D, less so as ideas move toward demonstration and deployment. In this case, government R&D policies can complement the use of a market-based approach to reducing greenhouse gas emissions and yield large benefits to society. A policy that broadly incentivizes energy R&D is more likely to maximize social returns than a narrow one targeted at a specific technology because it allows the market, rather than the government, to pick winners. Likewise, funding efforts in support of basic R&D are less likely to crowd out private investment because differences between private and social returns to innovation are largest for basic R&D.

In its 2011 proposed budget, the Administration has stated a commitment to fund R&D as part of its comprehensive approach to transform the way we use and produce energy while addressing climate change. The Recovery Act investments begun in 2009 are a first step in this clean energy transformation. They fall into eight categories that are briefly described here.

Energy Efficiency. The Recovery Act promotes energy efficiency through investments that reduce energy consumption in many sectors of the economy. For instance, the Act appropriates \$5 billion to the Weatherization Assistance Program to pay up to \$6,500 per dwelling unit for energy efficiency retrofits in low-income homes. The Recovery Act also appropriates \$3.2 billion to the Energy Efficiency and Conservation Block Grant program, most of which will go to U.S. states, territories, local governments, and Indian tribes to fund projects that improve energy efficiency, reduce energy use, and lower fossil fuel emissions.

Renewable Generation. The Recovery Act investments in renewable energy generation also are leading to the installation of wind turbines, solar panels, and other renewable energy sources. The Energy Information Administration projects that the fraction of the Nation's electricity generated from renewable energy, excluding conventional hydroelectric power, will grow from 3 percent in 2008 to almost 7 percent in 2012 in large part because of the renewal of Federal tax credits and the funding of new loan guarantees for renewable energy through the Recovery Act (Department of Energy 2009a).

Grid Modernization. As the United States transitions to greater use of intermittent renewable energy sources such as wind and solar, the Recovery Act is financing the construction of new transmission lines that can support electricity generated by renewable energy. The Act is also investing in new technologies that will improve electricity storage capabilities and the monitoring of electricity use through "smart grid" devices, such as sophisticated electric meters. These investments will improve the reliability, flexibility, and efficiency of the Nation's electricity grid.

Advanced Vehicles and Fuels Technologies. The Recovery Act is funding research on and deployment of the next generation of automobile batteries, advanced biofuels, plug-in hybrids, and all-electric vehicles, as well as the necessary support infrastructure. These efforts are expected to reduce the Nation's dependence on oil in the transportation sector.

Traditional Transit and High-Speed Rail. Grants from the Recovery Act also will help upgrade the reliability and service of public transit and conventional intercity railroad systems. For example, \$8 billion is going to improve existing, or build new, high-speed rail in 100- to 600-mile intercity corridors. Investments in high-speed rail and public transit will increase energy efficiency by improving both access and reliability, thus making it possible for more people to switch to rail or public transit from autos or other less energy-efficient forms of transportation.

Carbon Capture and Storage. One approach to limiting greenhouse gas emissions is to capture and store carbon from fossil-fuel combustion to

keep it from entering the atmosphere. The abundance of coal reserves in the United States makes developing such technologies and overcoming barriers to their use a particular priority. For instance, technology to capture carbon dioxide emissions has been used in industrial applications but has not been used on a commercial scale to capture emissions from power generation. Likewise, although some carbon has been stored deep in the ocean or underground in depleted oil reservoirs, questions remain about the permanence of these and other types of storage. The Recovery Act is funding crucial research, development, and demonstration of these technologies.

Innovation and Job Training. The Recovery Act is also investing in the science and technology needed to build the foundation for the clean energy economy. For instance, a total of \$400 million has been allocated to the Advanced Research Projects Agency-Energy (ARPA-E) program, which funds creative new research ideas aimed at accelerating the pace of innovation in advanced energy technologies that would not be funded by industry because of technical or financial uncertainty. The Recovery Act also helps fund the training of workers for jobs in the energy efficiency and clean energy industries of the future.

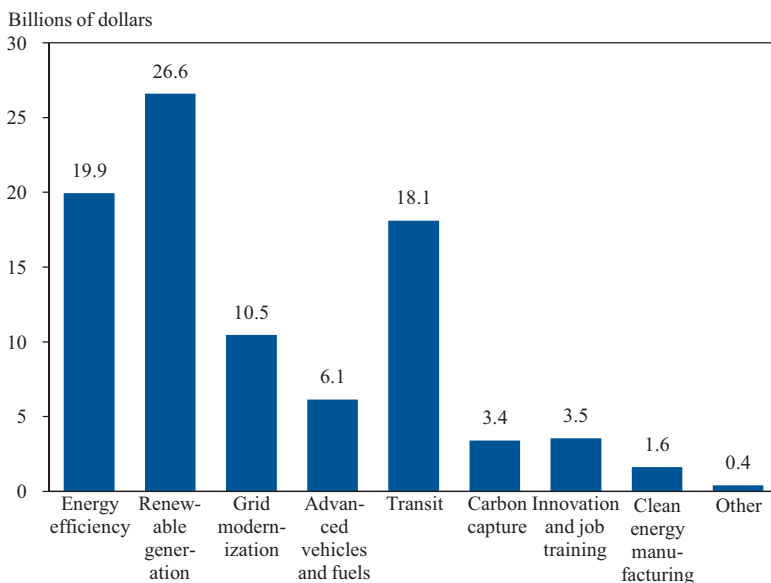
Clean Energy Equipment Manufacturing. The Recovery Act investments are increasing the Nation's capacity to manufacture wind turbines, solar panels, electric vehicles, batteries, and other clean energy components domestically. As the United States transitions away from fossil fuels, demand for advanced energy products will grow, and these investments in clean energy will help American manufacturers participate in supplying the needed goods.

Total Recovery Act Energy Investments. The Recovery Act is investing in 56 projects and activities that are related to transitioning the economy to clean energy. Forty-five are spending provisions with a total appropriation of \$60.7 billion, and another 11 are tax incentives that the Office of Tax Analysis estimates will cost \$29.5 billion through fiscal year 2019, for a total investment of over \$90 billion. In some cases, a relatively small amount of Federal investment leverages a larger amount of non-Federal support. Throughout this section, only the expected subsidy cost of the Federal investment is counted toward the appropriation.³

The largest clean energy investments from the Recovery Act go to renewable energy generation and transmission, energy efficiency, and transit. Figure 9-2 illustrates how this \$90 billion investment is distributed across the eight categories of projects described above, along with a ninth "other" category containing programs that do not fit elsewhere.

³ Because of the public nature of the Bonneville and Western Area Power Administrations, the accounting of clean energy investments described here measures the projected drawdown of the borrowing authority to these agencies as the Recovery Act appropriation.

Figure 9-2
Recovery Act Clean Energy Appropriations by Category



Source: Council of Economic Advisers (2010).

Because most of the clean energy investments involve grants and contracts that require that proposals be reviewed before funds are expended, not all of the money appropriated for these investments could be spent immediately. Thus, as with the Recovery Act more generally, only a portion of the appropriation has been spent. Over \$31 billion has been obligated and over \$5 billion has been outlayed through the end of 2009.⁴

Short-Run Macroeconomic Effects of the Clean Energy Investments

Using a macroeconomic model, the Council of Economic Advisers (CEA) estimates that the approximately \$90 billion of Recovery Act investments will save or create about 720,000 job-years by the end of 2012 (a job-year is one job for one year). Projects in the renewable energy generation and transmission, energy efficiency, and transit categories create the most job-years. Approximately two-thirds of the job-years represent work on clean energy projects, either by workers employed directly on the projects or by workers at suppliers to the projects. These macroeconomic benefits make it clear that the Administration has made a tremendous down payment on the clean energy transformation.

⁴ *Obligated* means that the money is available to recipients once they make expenditures, and *outlayed* means the government has reimbursed recipients for their expenditures. Energy-related tax reductions to date are included in the totals obligated and outlayed by the end of 2009.

OTHER DOMESTIC ACTIONS TO MITIGATE CLIMATE CHANGE

In his first year in office, the President took several other significant and concrete steps to transform the energy sector and address climate change. Significantly, the Environmental Protection Agency (EPA) issued two findings in December 2009. The first finding was that six greenhouse gases endanger public health and welfare. The second finding was that the emissions of these greenhouse gases from motor vehicles cause or contribute to pollution that threatens public health and welfare. These findings do not in and of themselves trigger any requirements for emitters, but they lay the foundation for regulating greenhouse gas emissions.

Following up on these findings, the Administration has proposed the first mandatory greenhouse gas emission standards for new passenger vehicles. The standards are expected to be finalized in the spring of 2010. By model year 2016, new cars and light trucks sold in the United States will be required to meet a fleet-wide tailpipe emissions limit equivalent to a standard of about 35.5 miles per gallon if met entirely through fuel economy improvements. The EPA estimates that these standards will save about 36 billion gallons of fuel and reduce vehicle greenhouse gas emissions by about 760 million metric tons in CO₂-equivalent terms over the lifetime of the vehicles.

The Administration also proposed renewable fuel standards consistent with the Energy Independence and Security Act (EISA), which requires that a minimum volume of renewable fuel be added to gasoline sold in the United States. Renewable fuels are derived from bio-based feedstocks such as corn, soy, sugar cane, or cellulose that have fewer life-cycle greenhouse gas emissions than the gasoline or diesel they replace. When fully implemented, the standards will increase the volume of renewable fuel blended into gasoline from 9 billion gallons in 2008 to 36 billion gallons by 2022.

The Administration also has been proactive in establishing minimum energy efficiency standards for a wide variety of consumer products and commercial equipment. For instance, standards were proposed or finalized in 2009 for microwave ovens, dishwashers, small electric motors, lighting, vending machines, residential water heaters, and commercial clothes washers, among others. Overall, these actions will reduce energy consumption and, in turn, greenhouse gas emissions. The Energy Information Administration's 2009 Annual Energy Outlook projected that by 2030, higher fuel economy and lighting efficiency standards will contribute to lowering energy use per capita by 10 percent, compared with fairly stable energy use per capita between 1980 and 2008 (Department of Energy

2009b). The 2010 Annual Energy Outlook highlights appliance and building efficiency standards as one reason for lower projected carbon dioxide emissions growth, underscoring the benefits of these regulations (Department of Energy 2009a).

Beginning in 2010, the United States will begin collecting comprehensive high-quality data on greenhouse gases from large emitters in many sectors of the economy (for instance, electricity generators and cement producers). When fully implemented, this program will cover about 85 percent of U.S. emissions. The information supplied will provide a basis for formulating policy on how best to reduce emissions in the future. It will also be a valuable tool to allow industry to track emissions over time. Specifically, these data will make it possible for industry and government to identify the cheapest ways to reduce greenhouse gas emissions.

Finally, the President issued an Executive Order requiring Federal agencies to set and meet aggressive goals for greenhouse gas emission reductions. Importantly, agencies are instructed to pursue reductions that lower energy expenses and save taxpayers money.

MARKET-BASED APPROACHES TO ADVANCE THE CLEAN ENERGY TRANSFORMATION AND ADDRESS CLIMATE CHANGE

Greenhouse gas emissions, as noted, are a classic example of a negative externality. Emitters of greenhouse gases contribute to climate change, thus imposing a cost on others that is not accounted for when making decisions about how to produce and consume energy-intensive goods. For this reason, policymakers should ensure that the market provides the correct signals to greenhouse-gas emitters about the full cost of their emissions. Once policy has ensured that markets are providing the correct signals and incentives, the operation of market forces can find the most effective and efficient paths to the clean energy economy. The President has included a market-based cap-and-trade approach in his 2010 and 2011 budgets as a way to accomplish this goal. This section describes the basics of this approach, including several potential ways to minimize compliance costs. It then discusses a specific proposal consistent with the President's goals for reducing greenhouse gas emissions.

Cap-and-Trade Program Basics

A cap-and-trade approach sets a limit on, or caps, total annual aggregate greenhouse gas emissions and then divides the cap into

emission allowances. These allowances are allocated to firms through some combination of an auction and free allocation.⁵ Firms may trade the allowances among themselves but are required to hold an allowance for each ton of greenhouse gas they emit. The aggregate cap limits the number of allowances available, ensuring their scarcity and thus establishing a price in the market for allowances. In this way, a cap-and-trade approach provides certainty in the quantity of emission reductions but allows the price of allowances to fluctuate with changes in the demand and supply.

Creating a market for greenhouse gas emissions gives firms flexibility in how they reduce emissions. Absent other regulatory requirements, a firm subject to the cap can choose to comply by changing its input mix (for instance, switching from coal to natural gas), modifying the underlying technology used in production (using more energy-efficient equipment, for example), or purchasing allowances from other entities with lower abatement costs. Such flexibility reaps rewards. A cap-and-trade program induces firms to seek out and exploit the lowest-cost ways of cutting emissions. It takes advantage of the profit motive and leverages private sector imagination and ingenuity to find ways to lower emissions.

Cap-and-trade programs already have proven successful. The United States has been using a cap-and-trade approach to reduce sulfur dioxide (SO₂) emissions since 1995. One study found that using a cap-and-trade approach instead of a performance standard to reduce sulfur dioxide emissions caused some firms to move away from putting scrubbers on their smokestacks to cheaper ways of meeting the cap, such as by blending different fuels (Burtraw and Palmer 2004). As a result, compliance costs of the SO₂ cap-and-trade program have been dramatically lower than predicted.

Finally, a cap-and-trade approach promotes innovation. A carbon price will give firms the certainty they need to make riskier long-term investments that could identify novel and substantially cheaper ways to reduce emissions. Evidence shows that pricing sulfur dioxide emissions through a cap-and-trade approach has produced patentable innovations as firms search for ever cheaper ways to abate (Burtraw and Szambelan 2009).

In the case of greenhouse gases, possible innovations range from new techniques to capture and store carbon generated by coal-burning electricity plants, to carbon-eating trees and algae, to the development of new types of renewable fuels. Indeed, such innovation—and the opportunity it provides

⁵ In his fiscal year 2011 proposed budget, the President supports using allowance revenue to compensate vulnerable families, communities, and businesses during the transition to the clean energy economy, as well as in support of clean energy technologies and adapting to the impacts of climate change.

to make the United States a world leader in clean energy technologies—is a key motivation for the Administration’s energy and climate policies.

Ways to Contain Costs in an Effective Cap-and-Trade System

There are a wide variety of ways to contain costs within a cap-and-trade framework. For instance, cap-and-trade programs may incorporate banking and borrowing of emission allowances over time, set ceilings or floors on allowance prices, or permit the use of offsets as ways to smooth the costs of compliance over time. A brief review of these mechanisms follows.

Banking and Borrowing. A cap-and-trade approach can be designed to give polluters flexibility in the timing of emission reductions through banking and borrowing. To limit allowance price volatility, sources can make greater reductions early if it is cheaper to do so and bank their allowances for future use. Likewise, firms can manage costs by borrowing against future reductions, allowing them to emit more today in return for more drastic reductions later.

Evidence shows that banking has played a particularly powerful role in helping firms to hedge uncertainty in the costs of the SO₂ cap-and-trade program over time. Anticipating that the cap originally set in 1995 would become more stringent in 2000, firms began to bank allowances for future use soon after the system was put in place. By 1999, almost 70 percent of available allowances in the market had been banked. Once the more stringent cap was in place, the banked allowances were drawn down to meet the cap, with about a 40 percent decrease in the size of the allowance bank between 2000 and 2005 (Environmental Protection Agency 2006).

In contrast, the inability of firms to bank or borrow in Southern California’s nitrous oxide market played a significant role in increased price volatility during the State’s electricity crisis in 2000 when firms met soaring demand for electricity by running old, dirty generators. One study found that the absence of banking and borrowing was an important contributing factor to the roughly tenfold increase in the price of nitrous oxide allowances, resulting in power plants subject to the cap eventually seeking exemption from the program (Ellerman, Joskow, and Harrison 2003).

Price Ceilings or Floors. While banking and borrowing allow firms to smooth costs over time, they may not guard against unexpected and potentially longer-lasting changes in allowance prices caused by such factors as a recession or economic boom, fuel price fluctuations, or unexpected variation in the pace of technological development. Consequently, cap-and-trade systems often include protections against prices that are deemed too high. For example, in the Northeast’s greenhouse gas trading system, allowance

prices above certain thresholds trigger additional flexibilities that reduce compliance costs.⁶

Another way for a cap-and-trade program to mitigate the effects of unexpected changes would be to specify an upper or lower limit, or both, on allowance prices. An upper limit protects firms and consumers from unexpectedly high prices. When the price reaches the upper limit, additional allowances are sold to prevent further escalation. A lower limit on allowance prices ensures that cheap abatement opportunities continue to be pursued. For example, cap-and-trade legislation recently passed by the U.S. House of Representatives reserves a small share of allowances to be auctioned if the price rises above a predetermined threshold and also sets a minimum price for allowances that are auctioned. One study finds that, for a given cumulative emissions reduction, a combined price ceiling and floor can reduce costs by almost 20 percent compared with a cap-and-trade program without any cost-containment mechanisms (Fell and Morgenstern 2009). On the other hand, it is possible that a floor or ceiling can cause total emissions to differ from the legislated cap.

Offsets. Offsets also can be an important cost-containment feature of a cap-and-trade program. Offsets are credits generated by reducing emissions in a sector outside the program; they can be purchased by a firm subject to the cap to meet its compliance obligations. Because greenhouse gases are global pollutants—they cause the same damage no matter where they are emitted—offsets offer the appealing prospect of achieving specified emissions reductions at a lower cost.

The purchase of offsets from the forestry and agricultural sectors could play a potentially important role in reducing the compliance costs of firms subject to the cap (Kinderman et al. 2008; Environmental Protection Agency 2009). And under some cap-and-trade programs, domestic firms may purchase international offsets to meet their compliance obligations. This possibility may encourage a foreign country to build a solar power plant rather than a coal plant so that it can sell the offsets in the U.S. market.

Despite these important advantages, however, it is crucial that the claimed reductions from offsets be real—otherwise the system will effectively provide payments without actually reducing emissions. Indeed, Europe’s experience with a project-based approach to international offsets suggests that concerns about the environmental integrity of claimed

⁶ Above \$7 per ton (in 2005 dollars), a firm can cover up to 5 percent of its emissions with domestic offsets, up from 3.3 percent. At \$10 per ton (in 2005 dollars plus a 2 percent increase per year), this amount increases to 10 percent of emissions and may include international offsets.

emissions reductions are well founded (Box 9-3).⁷ If offsets are going to be included as part of a cap-and-trade program, substantial investments in rigorous monitoring methods, such as combining remote sensing with on-the-ground monitoring, to verify greenhouse gas reductions are crucial.

Box 9-3: The European Union’s Experience with Emissions Trading

One of the pillars of the President’s proposed response to climate change is a cap-and-trade system to reduce U.S. emissions of greenhouse gases. The European Union’s Emission Trading Scheme (ETS), the world’s first mandatory cap-and-trade program for carbon dioxide emissions, was launched in 2005 to meet emission reduction targets agreed to under the Kyoto Protocol. The first phase of the ETS—from 2005 to 2007—applied to several high-emitting industrial sectors, including power generation, in 25 countries and covered just over 40 percent of all European Union (EU) emissions. Although data limitations and uncertainty over baseline emissions preclude researchers from assessing the precise magnitude of the reductions, one estimate suggests that the ETS reduced EU emissions by about 4 percent in 2005 and 2006 relative to what the level would have been in its absence. Because of the flexibility offered under the cap-and-trade program, these reductions occurred where it was cheapest to achieve them. That said, the ETS offers three important cautionary lessons as the United States explores how best to implement its own cap-and-trade system.

One lesson is the importance of carefully establishing a baseline for current and future emissions, so that the price sends an accurate signal to firms regarding how much to abate and innovate based on the expected future value of reductions. During the first phase of the ETS, EU countries allocated allowances based on firms’ estimates of their historic emissions. In April 2006, when monitoring data became available, the data showed that actual emissions were already below the cap. Allowance prices immediately fell from about €30 (\$38) per metric ton to less than €10 (\$13) before settling at €15–€20 (\$19–\$25) for the next few months.

The EU experience also demonstrates that distributing nearly all allowances to industry at no cost can lead to large windfall profits. The European Union distributed nearly 100 percent of allowances free to

Continued on next page

⁷ Cap-and-trade programs that allow project-level offsets are particularly susceptible to crediting activity that would have occurred anyway or that is replaced by high-carbon activities elsewhere (leakage). One way to reduce the potential for leakage is a sector- or country-based framework, in which sectors or governments receive credit in exchange for implementing policies to reduce emissions. The legislation passed by the U.S. House of Representatives includes a sector-based approach to international offsets.

Box 9-3, continued

firms subject to the cap in Phase 1 and only auctioned a small portion of allowances for Phase 2 (2008–12). One estimate (Point Carbon Advisory Services 2008) suggests that during Phase 2, electricity generators in Germany will reap the highest windfall profits of all participating EU countries, on the order of €14 billion to €34 billion (\$20 billion to \$49 billion). In countries with low-greenhouse-gas emitters, electricity generators are expected to benefit less. For instance, in Spain, windfall profits are estimated to be about €1 billion to €4 billion (\$1 billion to \$6 billion). In Phase 3 (2013–20), the European Union plans to auction the majority of allowances.

Finally, it is important to ensure that any offsets from domestic and international sources reflect real reductions. Otherwise, they may endanger the environmental integrity of the cap. The ETS allows limited use of project-based international offsets from the United Nations' Clean Development Mechanism (CDM) in place of domestic emission reductions. A review of a random sample of offset project proposals in the CDM program from 2004 to 2007 estimated that "additionality" was unlikely or questionable for roughly 40 percent of registered projects, representing 20 percent of emissions reductions, meaning they would have occurred anyway (Schneider 2007). Although the CDM has worked to improve its accounting procedures over time, the EU's experience demonstrates the importance of designing an offsets program carefully.

Coverage of Gases and Industries

Although carbon dioxide made up about 83 percent of U.S. greenhouse emissions in 2008, a cap-and-trade approach that gives firms flexibility in where they reduce emissions, both in terms of the greenhouse gas and the economic sector, can lower firms' compliance costs. One study found that achieving an emission goal by cutting both methane and carbon dioxide emissions rather than carbon dioxide alone could reduce firms' abatement costs in the United States by over 25 percent in the medium run (Hayhoe et al. 1999).

Costs are also affected by the number of industries covered by the cap, with the general principle being that greater coverage lowers the marginal cost of emissions reductions. A recent study comparing alternative ways to achieve a 5 percent reduction in emissions found that the cap-and-trade program's costs to the economy were twice as large when manufacturing was excluded as they were under an economy-wide approach (Pizer et al. 2006).

The American Clean Energy and Security Act

In June 2009, the U.S. House of Representatives passed legislation—the American Clean Energy and Security Act (ACES)—that includes a cap-and-trade program consistent with the President’s goal of reducing greenhouse gas emissions by more than 80 percent by 2050, and the Senate is currently engaged in a bipartisan effort to develop a bill.

Projected Climate Benefits. Based on two analyses of the ACES legislation, U.S. actions would reduce cumulative greenhouse gas emissions by approximately 110 billion to 150 billion metric tons in CO₂-equivalents by 2050 (Paltsev et al. 2009; Environmental Protection Agency 2009). The EPA estimates that emission reductions of this magnitude, when combined with comparable action by other countries consistent with reducing world emissions by 50 percent in 2050, is expected to limit warming in 2100 to less than 2 °C (3.6 °F) relative to the pre-industrial global average temperature, with a likely range of about 1.0 to 2.5 °C (1.8 to 4.5 °F).

To derive the possible benefits associated with the U.S. contribution to these emission reductions, the CEA calculates that the ACES will result in approximately \$1.6 trillion to \$2.0 trillion of avoided global damages in present value terms between 2012 and 2050 (in 2005 dollars).⁸ The value of avoided damages includes such benefits as lower mortality rates, higher agricultural yields, money saved on adaptation measures, and the reduced likelihood of small-probability but high-impact catastrophic events. Further, the benefits will be significantly larger if U.S. policy induces other countries to undertake reductions in greenhouse gas emissions.

Projected Economic Costs. The estimated cost of meeting the caps outlined in the ACES legislation is relatively small. Recent research suggests that the ACES will result in a loss of consumption on the order of 1 to 2 percent in 2050 (Environmental Protection Agency 2009; Paltsev et al. 2009). On a per household basis, the average annual consumption loss would be between \$80 and \$400 a year between 2012 and 2050 (in 2005 dollars).

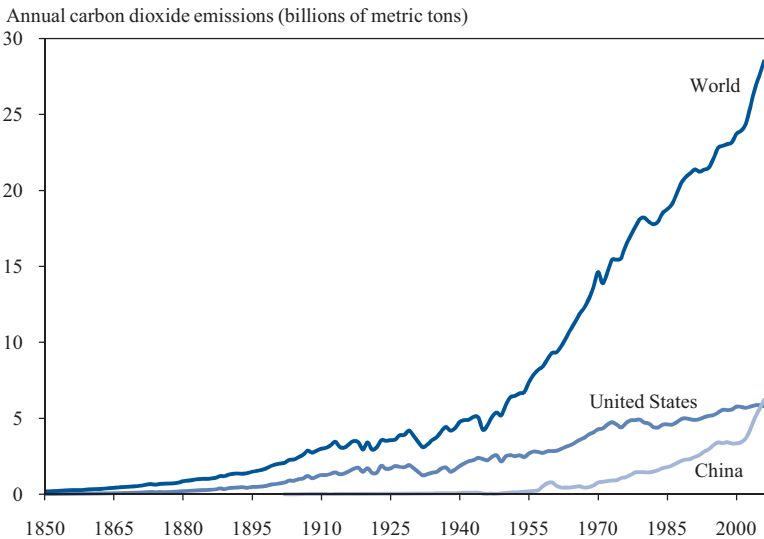
⁸ The CEA uses estimates of the projected decline in emissions between 2012 and 2050 based on the President’s proposed reductions in emissions and uses the central estimate of \$20 a ton for a unit of carbon dioxide emitted in 2007 (in 2007 dollars) that was recently developed as an interim value for regulatory analyses (Department of Energy 2009c). Additionally, it assumes that the benefit of reducing one additional ton of carbon dioxide grows at 3 percent over time and that future damages from current emissions are discounted using an average of 5 percent. Several Federal agencies have used these values in recent proposed rulemakings but have requested comment prior to the final rulemaking, so these estimates may be revised.

INTERNATIONAL ACTION ON CLIMATE CHANGE IS NEEDED

Greenhouse gas emissions impose global risks. As a result, just as U.S. efforts to reduce emissions benefit other countries, actions that other countries take to mitigate emissions benefit the United States. Given the global nature of the problem and the declining U.S. share of greenhouse gas emissions, U.S. actions alone to reduce those emissions are insufficient to mitigate the most serious risks from climate change.

Developing countries such as China and India are responsible for a growing proportion of emissions because of their heavy reliance on carbon-intensive fuels, such as coal (Figure 9-3). In 1992, China's carbon dioxide emissions from fossil fuel combustion were half those of the United States and represented 12 percent of global emissions. By 2008, China's carbon dioxide emissions represented 22 percent of global emissions from fossil fuels, exceeding the U.S. share of 19 percent and the European share of 15 percent. China's share of global emissions is projected to grow to about 29 percent by 2030 absent new emission mitigation policies. By contrast, the U.S. share of global emissions is projected to fall to about 15 percent by 2030 even absent new emission mitigation policy. Thus, cooperation by both

Figure 9-3
United States, China, and World Carbon Dioxide Emissions



Notes: The figure includes carbon dioxide emissions from fossil fuel consumption, cement manufacturing, and natural gas flaring. Notably, this figure does not include changes in carbon dioxide emissions from land-use change.

Source: World Resources Institute, Climate Analysis Indicators Tool.

past and future contributors to emissions will be required to stabilize the atmospheric concentrations of greenhouse gases.

In keeping with this goal, the Administration has actively pursued partnerships with major developed and emerging economies to advance efforts to reduce greenhouse gas emissions and promote economic development that lowers emission intensity.

Partnerships with Major Developed and Emerging Economies

The President has worked to further a series of international agreements to address climate change. For example, he launched the Major Economies Forum on Energy and Climate to engage 17 developed and emerging economies in a dialogue on climate change. In July, the leaders of these countries agreed that greenhouse gas emissions should peak in developed and developing countries alike, and recognized the scientific view that the increase in global average temperature above pre-industrial levels ought not to exceed 2 °C (3.6 °F). They also agreed to coordinate and dramatically increase investment in research, development, and deployment of low-carbon energy technologies with a goal of doubling such investment by 2015. Finally, the leaders agreed to mobilize financial resources in support of mitigation and adaptation activities, recognizing that the group should be responsive to developing-country needs in this area.

Also in July, leaders from the Group of Eight (G-8) countries agreed to undertake robust aggregate and individual medium-term emission reductions consistent with the objective of cutting global emissions by at least 50 percent by 2050. Additionally, under the Montreal Protocol, the United States jointly proposed with Canada and Mexico to phase down emissions of hydrofluorocarbons, a potent greenhouse gas used in refrigeration, fire suppression, and other industrial activities. This action alone would achieve about 10 percent of the greenhouse gas emission reductions needed to meet the agreed G-8 goal of a 50 percent reduction by 2050.

In December, the Administration worked with major emerging economies, including Brazil, China, India, and South Africa, developed countries, and other regions around the world to secure agreement on the Copenhagen Accord. For the first time, the international community established a long-term goal to limit warming of global average temperature to no more than 2 °C (3.6 °F). Also for the first time, all major economies agreed to take action to address climate change. Under the Accord, both developed and major emerging economies are in the process of submitting their emission mitigation commitments and actions to reduce greenhouse gas emissions. Every two years, developing countries will report on emission mitigation efforts, which will be subject to international consultation and

analysis under clearly defined guidelines. Establishing transparent review of developed and developing country mitigation activities will help ensure that countries stand behind their commitments.

Furthermore, under the Accord, in the context of meaningful mitigation actions and transparency, developed countries committed to a goal of jointly mobilizing \$100 billion a year in funding from a variety of private and public sources for developing countries by 2020. This funding will build on an immediate effort by developed countries to support forestry, adaptation, and emissions mitigation with funding approaching \$30 billion sometime in the 2010 to 2012 timeframe. There will be a special focus on directing this funding to the poorest and most vulnerable developing countries.

Phasing Out Fossil Fuel Subsidies

The United States also spearheaded an agreement in September to phase out fossil fuel subsidies among G-20 countries, a goal seconded by countries in the Asian-Pacific Economic Cooperation (APEC) in November. The G-20 also called on all nations to phase out such subsidies worldwide. Fossil fuel subsidies are particularly large in non-OECD countries, such as India and Russia. Twenty of the largest non-OECD governments spent about \$300 billion on fossil fuel subsidies in 2007. Together, this coordinated action to reduce subsidies can free up resources, especially in developing countries, to target other social needs such as public health and education. One model estimates that eliminating fossil fuel subsidies in the major non-OECD countries alone would reduce greenhouse gas emissions by more than 7 billion metric tons of CO₂-equivalent, enough to fulfill almost 15 percent of the agreed-upon G-8 goal of reducing global emissions by 50 percent by 2050 (Organisation for Economic Co-operation and Development 2009).

In the United States, these subsidies—including tax credits, deductions, expensing practices, and exemptions—are worth about \$44 billion in tax revenues between 2010 and 2019. Their elimination will help put cleaner fuels, such as those derived from renewable sources, on a more equal footing and reduce wasteful consumption of fossil-fuel based energy caused by underpricing. Proper pricing of fossil fuels will also help reduce reliance on petroleum, thus enhancing energy security and aiding in the achievement of climate mitigation goals.

CONCLUSION

Today's economy is dependent on carbon-intensive fuels that are directly linked to an increase in global average temperature. Continued

reliance on these fuels will have a range of negative impacts, including increased mortality rates, reduced agricultural productivity in many locations, higher sea levels, and the need for costly adaptation efforts. For these reasons, a clean energy transformation is essential.

Through his comprehensive plan, the President has set the country on course to achieve this goal. He has taken several significant and concrete steps to transform the energy sector and address climate change through the American Reinvestment and Recovery Act and through targeted regulation. To address externalities associated with greenhouse gas emissions, the President has proposed a market-based cap-and-trade approach. These combined efforts will stimulate the research and development necessary to advance new clean energy technologies. Because of the global nature of the climate change problem, the Administration is also actively pursuing partnerships with other countries to advance efforts to transition the world to clean energy and reduce greenhouse gas emissions.