THE HAMILTON PROJECT

STRATEGY PAPER
MAY 2011

A Strategy for America's Energy Future: Illuminating Energy's Full Costs

Michael Greenstone and Adam Looney

MISSION STATEMENT

The Hamilton Project seeks to advance America's promise of opportunity, prosperity, and growth. The Project's economic strategy reflects a judgment that long-term prosperity is best achieved by fostering economic growth and broad participation in that growth, by enhancing individual economic security, and by embracing a role for effective government in making needed public investments. We believe that today's increasingly competitive global economy requires public policy ideas commensurate with the challenges of the 21st Century. Our strategy calls for combining increased public investments in key growth-enhancing areas, a secure social safety net, and fiscal discipline. In that framework, the Project puts forward innovative proposals from leading economic thinkers — based on credible evidence and experience, not ideology or doctrine to introduce new and effective policy options into the national debate.

The Project is named after Alexander Hamilton, the nation's first treasury secretary, who laid the foundation for the modern American economy. Consistent with the guiding principles of the Project, Hamilton stood for sound fiscal policy, believed that broad-based opportunity for advancement would drive American economic growth, and recognized that "prudent aids and encouragements on the part of government" are necessary to enhance and guide market forces.

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BROOKINGS

Abstract

Energy consumption is critical to economic growth and our quality of life. America's energy system, however, is malfunctioning. The status quo is characterized by a tilted playing field, where our energy choices are based on the visible costs that appear on utility bills and at the gas pump. This system masks the social costs arising from those energy choices, including shorter lives, higher health care expenses, a changing climate, and weakened national security. As a result, we pay unnecessarily high costs for energy. New "rules of the road" are needed to improve our living standards.

In this paper, The Hamilton Project provides four principles for reforming America's energy policies. First, a level playing field requires that the full costs of different energy sources be priced. Second, basic research, development, and demonstration are essential for energy innovation, but government funding is required for critical investments that the private sector does not have the incentives to undertake. Third, environmental regulations should be designed and implemented as efficiently as possible. Finally, climate change, as a problem of global scope, should be addressed on a global scale.

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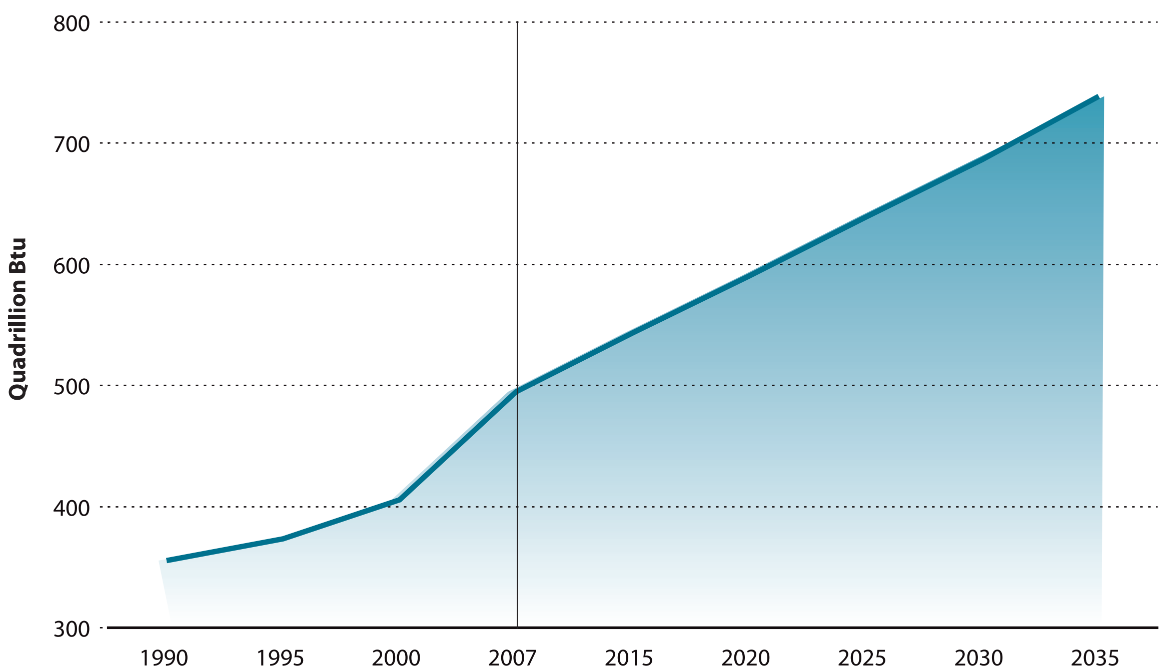
Chapter 1: Introduction

Whether by heating our homes in winter, keeping the lights on in our offices, powering factories that manufacture our goods, or fueling our automobiles, energy drives our economy and supports our quality of life. Thanks in part to an economic infrastructure heavily dependent on energy use—roads and highways, ports and railways, broadband and computer networks, manufacturing plants and shipping facilities—American workers and businesses are among the most productive in the world and the most globally integrated. One innovation after another over the centuries, fueled by cheap and plentiful energy from coal, oil, and natural gas, has allowed the nation's economy to transition from one based on agriculture to one based on high-value-added manufacturing and services aided by computerization. Our standard of living—among the highest on earth—would simply not be possible without energy and the systems that have been developed to harness it.

Elsewhere in the world, developing economies are rapidly trying to catch up—both in terms of economic growth and quality of life—and are ramping up their energy production infrastructures accordingly. For example, major rural electrification projects are underway in China and India to increase access to energy in villages and to mechanize farming tasks. Furthermore, both countries are rapidly expanding electricity production to feed their rapid industrial growth. Abroad as at home, rising living standards and robust economic growth require access to plentiful, reliable, and inexpensive energy.

FIGURE 1

Projections of World Energy Consumption



Source: EIA 2010c

Unfortunately, the sources of energy we have grown to rely on are more expensive than we once thought. The true cost of energy includes not just the price we pay at the gas pump or what shows up on the electric bill, but also the less obvious impact of energy use on health, the environment, and national security. Economists refer to this more holistic accounting as the "social costs" of energy consumption. Recent events like the Deepwater Horizon oil spill, the death of twenty-nine West Virginia coal miners in the worst mining disaster in twenty-five years, and the crisis at Japan's Fukushima Daiichi nuclear plant are particularly salient examples of the health and environmental costs, and economic risks, of our current energy sources. While these tragic disasters are the most obvious symbols of these costs, they are by no means the largest.

Our primary sources of energy impose significant health costs on our citizens—particularly among infants and the elderly, our most vulnerable. For instance, even though many air pollutants are regulated under the Clean Air Act, fine particle pollution, or "soot," is estimated to still contribute to roughly one out of every twenty premature deaths in the United States (EPA 2010b). Indeed, soot from coal power plants alone is estimated to cause thousands of premature deaths and hundreds of thousands of cases of illness each year (Abt Associates 2004). The resulting economic damages include costs from days missed at work and school due to illness, increases in emergency room and hospital visits, and other economic losses associated with premature deaths. In other countries the costs are still greater; recent research suggests that life expectancies in Northern China are about five years shorter than in Southern China due to the higher pollution levels in the north (Chen, Ebenstein, Greenstone, and Li 2011).

In total, the National Academy of Sciences recently estimated total non-climate change-related damages associated with energy consumption and use at more than $120 billion in the United States in 2005, nearly all of which resulted from the effects of air pollution on our health and wellness (NAS 2010).

The social costs associated with using carbon-intensive fuels also include climate change. If carbon dioxide (CO_2) emissions continue to rise at the current rate, they are likely to drive temperature changes that have significant environmental and health consequences: rising sea levels, storms that are more frequent and more severe, increased flooding and drought, and other dramatic changes in weather patterns. These changes in turn could result in an increase in water- and insect-borne diseases as well as in the loss of biodiversity and, due to floods or droughts, the loss of human lives and livelihoods (Intergovernmental Panel on Climate Change [IPCC] 2007). The U.S. government recently developed a measure to monetize the damages caused by CO_2 emissions—the social cost of carbon (SCC). By this metric, carbon emissions in the United States resulted in almost $120 billion in damages globally in 2009 (Interagency Working Group of the Social Cost of Carbon, United States Government [2010]; EPA 2011).

Other environmental costs associated with our current energy sources include the impact of acid rain on vegetation and lakes, the effect of ozone on agricultural productivity, oil leaks and spills, and land use issues related to fuel extraction.

Finally, there are other economic, political, and national security risks associated with current domestic energy policies. Oil still plays an important role in the American economy: it powers most of our transportation sector and is an important input in many industries. Continuing turmoil in the Middle East has raised the profile of energy security and the geopolitical implications of reliance on oil. In part to protect major oil supplies, the United States has maintained a military presence in the Middle East for more than fifty years. On several occasions, it has become mired in military interventions in part to prevent oil supply disruptions, among other objectives.

America's energy system is malfunctioning precisely because we have chosen "rules of the road" that mask the health, climate, and security costs of energy consumption. Under the current rules, we primarily acknowledge the direct cost

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of producing energy—the cost of fueling a coal-fired power plant, for example—without adequately capturing the very real, long-term costs to society caused by burning this coal in the forms of shortened life spans, illness, and damage to Earth's climate.

For example, we estimate that it costs about 3.2¢ for an existing coal plant to produce a kilowatt hour (kWh) of electricity (see Table 1). This appears to be a bargain but the reality is that this kWh causes 5.6¢ of damages to our wellbeing. Although these costs are not listed on our monthly utility bills, they are nevertheless real—they show up in shorter lives, higher health-care bills, and a changing climate that poses risks to our way of life. Put bluntly, the true cost exceeds the costs on utility bills by more than 170 percent.

There has been much debate at all levels of government about U.S. energy policy and numerous proposals to change the "rules of the road" for energy production and consumption. It is hardly surprising that Congress and the executive branch have, for years, been unable to agree on a clear path forward. This is because we are dealing with a very complicated situation requiring a series of trade-offs. A change in the rules that govern our energy choices would have some costs and some benefits, and would likely change the distribution of benefits.

In the short-term, the economic impacts of incorporating the social costs of energy sources into the prices individuals and firms pay would be significant. Utility bills and the price paid at the pump would increase, making our current quality of life more expensive and adding costs to energy-intensive industries. On the other hand, current and future Americans would be getting something back in the exchange. Indeed, the benefits to health, safety, and other economic and environmental factors that contribute to our quality of life are vast. Climate change endangers human health and safety and the environment, although there is some uncertainty as to the degree of damage that would occur. By reducing those risks, policy-makers hold the key to generating tremendous benefits through longer and healthier lives, an environment that poses fewer risks, and strengthened national security.

To create the most value for society, policy-makers could implement a new set of rules to help make sure that we pursue those energy policies for which the benefits to users and society as a whole exceed their true costs. These policies would all move us toward an approach to energy policy that no longer tilts the rules of the road in favor of energy sources that only appear cheap because their costs to our health, the climate, and national security are obscured or indirect. The result would be a system in which we leverage market forces to decide the best outcome based on full and accurate comparisons.

The following principles should serve as a guide to setting energy and climate policies that rebalance our energy use towards more sustainable sources:

1. **Appropriately price the social cost of energy production and use.** Fossil fuels such as coal, oil, and natural gas have costs beyond what users pay to the utility company or at the gas pump. These costs—ranging from increases in lung disease and infant mortality to problems associated with climate change—have been quantified and can be expressed in dollar terms. As argued in the Hamilton Project paper, "An Economic Strategy to Address Climate Change and Promote Energy Security" (Furman, Bordoff, Deshpande, and Noel 2007), the best approach is to directly price these costs through cap-and-trade or tax policies. If firms and consumers faced the full cost of their energy use, they would have a greater incentive to make more-informed and socially efficient decisions about energy consumption.

2. **Fund basic research, development and demonstration.** Many believe that technological innovations will ultimately be the solution to finding cleaner low-cost energy sources—in other words, that we will innovate our way out of the energy and climate change debate. The problem with this belief is that there is little incentive for the private sector to undertake either basic research or technology demonstration projects that are good for society because these may not offer the promise of a profitable private return. One impediment is the lack of a clear price signal that provides the right incentive for innovation. A second impediment is the fact that the fruits of basic research and demonstration investments—ideas and methods, as well as information about the commercial viability of these innovations—are hard to capture as they are easily shared among competitors. This impediment would exist even in the presence of a cap-and-trade or tax based on carbon's social costs. This creates a critical role for government research to provide funding and support for the types of basic research that could help facilitate the creation of low-cost, clean energy sources to compete with oil, gas, and coal in the American marketplace.

3. **Make regulations more efficient.** Regulation has played and will continue to play a significant role in addressing the environmental and health consequences of energy consumption. The current process for promulgating regulations needs to be updated to promote rules that are more efficient and cost-effective. By requiring cost-benefit analysis (CBA) to evaluate the potential impact of regulations and assessing the reliability of empirical studies that are used to complete CBA, we can greatly enhance the effectiveness and reputation of our environmental regulatory system. Furthermore, to ensure their ongoing value, a retrospective review of regulations is imperative. Finally, genuine reform may involve rethinking and potentially eliminating regulations that become superfluous or counterproductive after energy sources are priced.

4. **Address climate change on a global scale.** Climate change is distinct from many environmental and energy-related issues in that it is global in scope and requires a global effort to address. Although the United States is a leading emitter today, in the future the bulk of emissions growth will come from developing countries. From a pragmatic standpoint, this means that any viable effort to address climate change must involve a coordinated approach by many countries. Negotiations have been complicated, however, and there are smaller steps that can be taken immediately to start us on a path toward a global solution. This effort can begin today with a number of measures such as building the capability to monitor total net emissions at the country level (this could be a building block for a trading system) through satellite technology. This would provide evidence of carbon emissions by countries and eliminate issues surrounding the accuracy of reporting, which has been a stumbling block in international negotiations.

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Chapter 2: Energy Use is Vital to Well-Being, But Many Forms of Energy Have Hidden Costs

A. THE BENEFITS OF ENERGY USE

The development and exploitation of inexpensive energy sources has been a key driver of economic development and quality of life. The story of the expansion of the U.S. economy, and of the advances and innovations that have made life better for Americans, leaps from one energy-harvesting invention to another: the cotton gin, the steam engine, the light bulb, the internal combustion engine, the turbine, the mechanized factory, the electrified city, and the computer. The development of coal, oil, natural gas, and nuclear power made all this progress possible and has helped support activity that is integral to our economy and quality of life.

Windmills and watermills, the first modes of generating mechanical energy, were used almost entirely for rudimentary tasks such as grinding grain and pumping water. The development of the steam engine in Britain in the mid-eighteenth century gave birth to industry by powering factories and cotton mills. In the late nineteenth century, the internal combustion engine, which runs our entire modern motor vehicle fleet, was invented. Around the same time, the light bulb was developed, allowing businesses to keep their doors open even after the sun had set, making it possible for employees to extend their work days.

Today our economy is heavily reliant on electric power to run businesses and maintain quality of life. Data centers and server farms in the United States require massive amounts of energy. In 2006, they consumed 61 billion kWh of electricity (1.5 percent of total U.S. electricity consumption)—more than was consumed by the nation's televisions (EPA 2007). Oil fuels more than 90 percent of the nation's vehicle motor fleet and is a critical fuel input for the entire transportation network. The benefits that energy provides, from home heating to facilitation of trade, are integral parts of our way of life. The United States consumes about one-fifth (21 percent) of the world's energy, despite having less than 5 percent of the world's population (EIA 2010a).

But U.S. dominance in energy use is about to change. The developing world—especially China and India—are rapidly increasing the amount of energy they consume as their economies grow and their citizens aspire to better living conditions (Figure 2). As important as access to plentiful energy is to maintaining the standard of living in the United States, access to energy has taken on an even more vital role in emerging markets as those markets transition to a higher standard of living and more energy-intensive economies.

A lack of reliable access to energy has been a major deterrent to economic growth and improved quality of life in most of the developing world. Almost one-fourth of the world's population—most of whom live in Sub-Saharan Africa and South Asia—lacks access to electricity (IEA 2010). Twice that number—half the world's population—lacks access to clean cooking energy and relies on traditional biomass fuels (wood, dung, coal, and agricultural by-products) that produce smoke and other air pollutants (UNDP/WHO 2009). For example, it is believed that indoor smoke from solid fuels was the sixth-leading cause of death and fifth-leading cause of disability in low-income countries in 2004 (WHO 2009). "Energy poverty"

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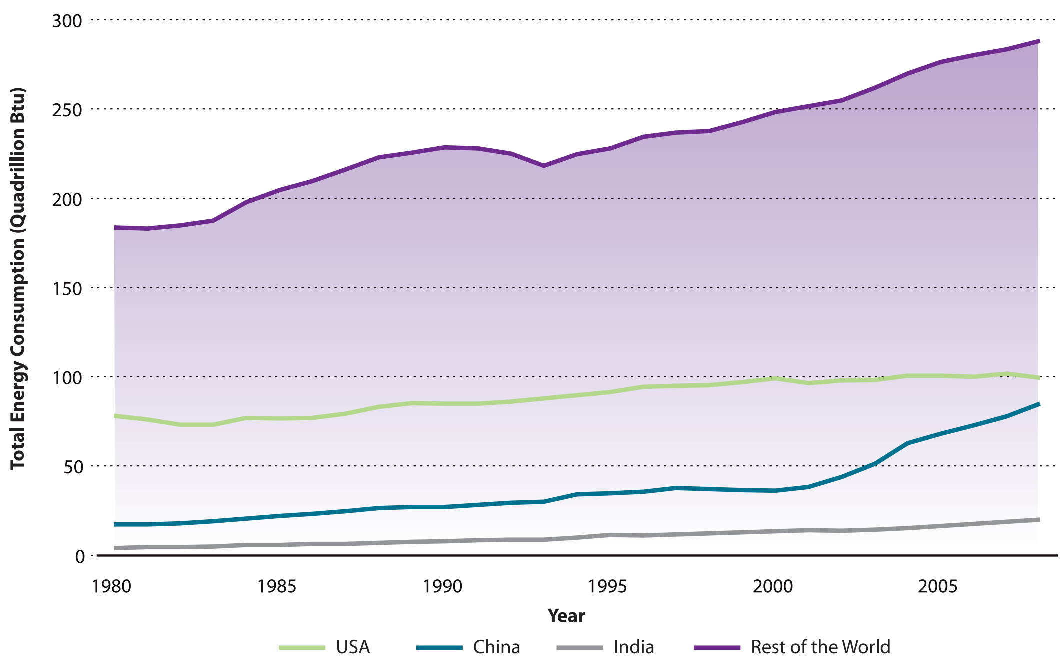
FIGURE 2

World Energy Consumption by Country



Source: EIA 2009b

and "fuel poverty" contribute to poverty, health problems that can result in lower life expectancy, diminished access to education and other productive activities, and lower rates of economic growth and productivity.

From facilitating trade to raising income and improving health, reliable access to energy could help reduce poverty and improve life expectancy in developing nations around the world. As these nations grow and transition, however, their reliance on fossil fuel–based energy sources will surge, creating another set of global challenges resulting from climate change.

B. THE SOCIAL COSTS OF ENERGY USE

The benefits of the energy sources that we currently rely on are obvious. But it is increasingly clear that the costs of our current sources go well beyond what we pay at the pump or to the utility company. These additional costs of energy use take on a variety of forms, from the erosion of living standards, to the diversion of taxpayer funds and other critical resources. They include increased health costs, shortened life spans, higher military expenditures and foreign policy constraints, expensive environmental clean-ups, and the broad impacts of climate change—all of which create a substantial debt that we are imposing on future generations.

1. Health effects of current energy sources

The combustion of fossil fuels results in the release of pollutants that have a significant impact on the health and well-being of our society and the world as a whole. It is easy to think of climate change as an environmental issue, and to focus on melting glacier caps or the loss of habitat. However, the greatest costs to society of air pollution come from health impacts, which make up approximately 94 percent of non-climate social costs (Muller and Mandelsohn 2007). Particulate air pollution, or soot, is associated with elevated mortality rates for adults and infants (Chay and Greenstone 2003a). In 2010, soot from U.S. coal-fired power plants was estimated to have caused 23,600 premature deaths and more than 500,000 cases of respiratory illness (Abt Associates 2004). Soot and other pollutants such as sulfur dioxide (SO2), carbon monoxide (CO), and nitrogen oxides (NOx), which lead to ozone, all pose threats to well-being, including higher mortality rates, more hospital admissions, restricted activity days, and increased expenditures on medications for respiratory problems (Deschenes, Greenstone, and Shapiro 2011). Beyond direct health costs, pollution-induced illness also results in economic damages from lost days of work or school and lower productivity on the job (Currie, Hanushek, Kahn, Neidell, and Rivkin 2009; Graff Zivin and Neidell 2011; Hanna and Oliva 2011).

All told, when translated to dollar costs, electricity generation from coal, oil-fueled vehicles and transportation, and electricity production from natural gas caused an estimated $120 billion in non-climate change-related damages in 2005 (Figure 3). Health-related damages account for almost all of these costs.

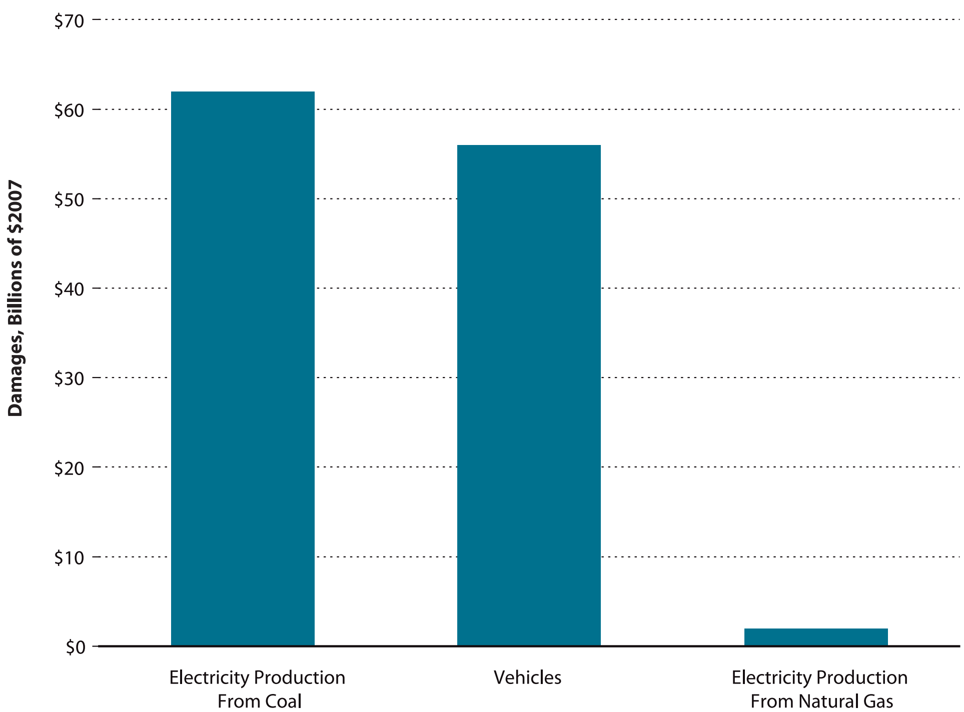
The health consequences of other energy sources can be severe, as the ongoing nuclear crisis in Japan reminds us. Prior experiences with nuclear disasters suggest that they increase the incidence of cancer. Even at doses once thought to be harmless, children born in regions of Sweden that experienced higher radiation fallout from the disaster at Chernobyl have been shown to have reduced cognitive abilities, measured by school performance (Almond, Edlund, and Palme 2009).

2. The social cost of carbon

Since the start of the industrial revolution, humans have been emitting a growing amount of greenhouse gases such as CO_2, methane, and NOx into the atmosphere. Figure 4 shows that the concentration of CO_2 in the atmosphere has risen by more than 23 percent over the past fifty years (KNMI Climate Explorer n.d.). According to the IPCC (2007), these rising levels of CO_2 and other greenhouse gases will cause rising average global temperatures in the coming years and decades. If current emissions trends continue, global temperatures will increase by an estimated 4.3°F to 11.5°F (2.4°C to 6.4 °C) by 2099, depending on the climate model and assumptions about economic growth (IPCC 2007).

FIGURE 3

Main Sources of Non-Climate-Change-Related Damages, 2005

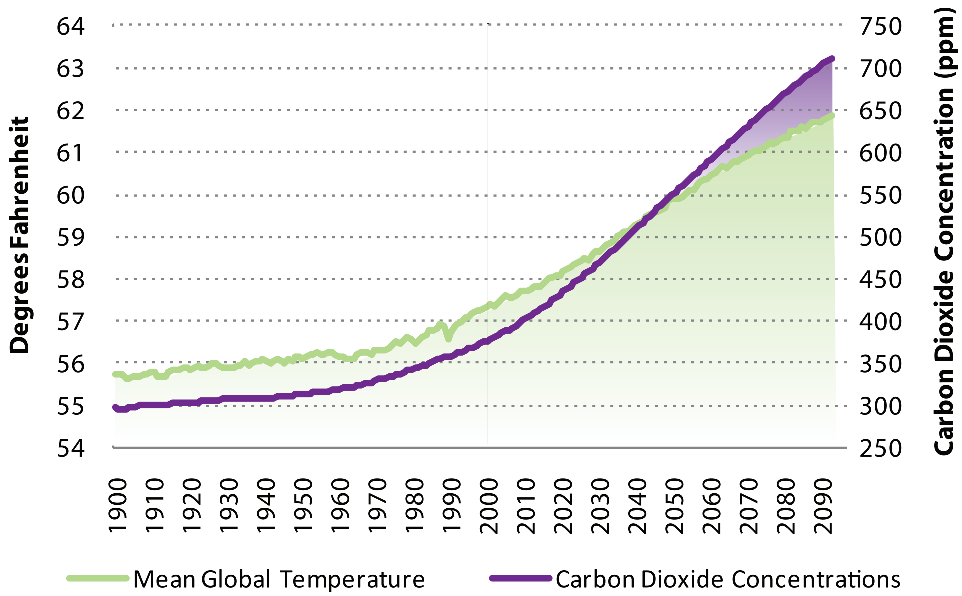


Source: NAS 2010.

Note: Vehicle costs refer to the total life-cycle costs of producing and operating vehicles.

FIGURE 4

Mean Global Temperature and Atmospheric CO_2 Concentrations

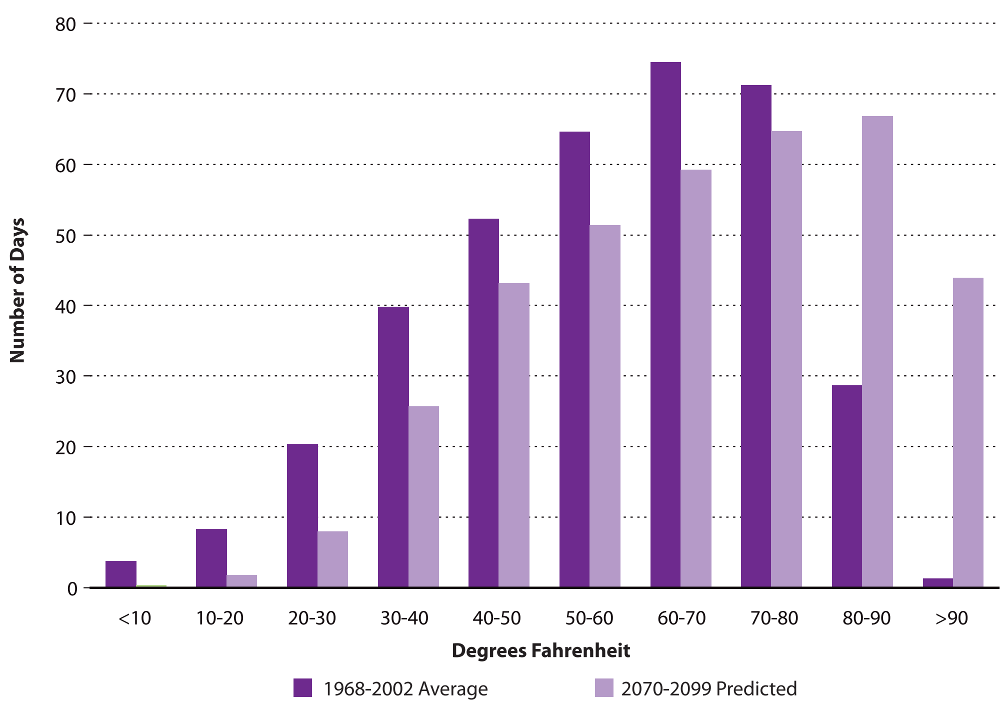


Source: KNMI Climate Explorer, n.d.

Note: Multimodel average temperature. SRES A1B scenario.

FIGURE 5

Current and Predicted End-of-Century Daily Temperatures



Source: Deschenes and Greenstone 2007.

Note: Hadley 3-A1FI predictions, error corrected.

The increase in average temperatures is well-documented, but it is less clear how this will affect our lives. One way to illustrate this effect is to look at the incidence of very hot days. Figure 5 reports the current number of days per year when the temperature experienced by the average American falls into certain ranges. In recent history, it has been extremely rare for the average daily temperature (calculated as the average of the daily maximum and minimum) to exceed 90°F—the average American experiences about one such day per year. But in the future such extremely hot days are projected to become a regular occurrence—rising to about forty a year. Thus the United States will experience roughly four times as many days when the temperature is hotter than 90°F than days when it is below 30°F. The troubling aspect of this project change is that the greatest damages from temperature in terms of elevated rates of mortality and morbidity and reduced agricultural productivity are concentrated at these high temperatures.

In addition to the increase in temperatures, the higher concentrations of greenhouse gases are expected to lead to a series of other changes on our planet, including changes in precipitation patterns, weather variability, and rising sea levels. Together, these changes in climate are expected to lead to a series of adverse outcomes ranging from reduced

BOX 1

Calculating the Social Cost of Carbon (SCC)

The U.S. government recently developed estimates of the SCC for use in regulatory analyses, and has used them regularly since their release. The 2009–2010 interagency process that developed these SCC values—the Interagency Working Group on the Social Cost of Carbon—was the first federal government effort to promote consistency in the way that agencies calculate the social benefits of reducing CO_2 emissions in regulatory impact analyses.[2]

The challenging task of monetizing the various costs of damages associated with greenhouse gas–driven climate change involves several steps. The first step is to translate emissions of greenhouse gases into atmospheric greenhouse gas concentrations, which are governed by the natural carbon cycle. The second step is to translate the atmospheric concentrations into changes in temperature based on models of the climate.

The final step is to project the economic damages associated with temperature changes. This step is made especially challenging by the fact that CO_2 remains in the atmosphere for decades, so any emissions today have consequences well into the future. That is, the damages from an additional unit of CO_2 emitted today results in damages today and for decades to come. Transforming the stream of economic damages over many years into a single value requires judgments about how to assign a value in today's dollars for damages that occur in the future.

An important question in setting the SCC is whether to include damages that are projected to occur outside the United States. The U.S. government chose a central cost based on global damages for two reasons. First, emissions of greenhouse gases contribute to damages around the world even when they are emitted in the United States. Consequently, to address the global nature of the problem, it is sensible to have the SCC incorporate the full global damages caused by greenhouse gas emissions. Second, climate change presents a problem that the United States cannot solve alone. Other countries also need to take action to reduce emissions if significant changes in the global climate are to be avoided. If the United States were to set policy based on global damages it could provide much-needed leadership for other countries. Given that most climate-related damages in the United States arise from foreign carbon emissions, it is imperative that other countries also adopt a global approach.

Taking all of these considerations into account, the Interagency Working Group on the Social Cost of Carbon (2010) calculated a range of estimates for use in regulatory analyses. For 2010, the central value of the SCC is estimated to be $21 per ton of CO_2 emissions. This figure includes the cost of changes in net agricultural productivity, effects on human health, property damages from increased flood risk, and the value of ecosystem services.

The SCC has already become a standard tool in the evaluation of national policy choices. Since the release of these SCC values, the monetized benefits of CO_2 emission reductions have been included in at least seven major regulations (those with costs or benefits above $100 million) across three federal departments and agencies.

agricultural productivity, increased mortality rates, higher flood risks, greater rates of species extinction, compromised ecosystem services, and even increased conflict over scarce natural resources. In addition, there is a rising concern about the possibility of a catastrophic event, such as a potentially discontinuous "tipping point" in the behavior of Earth's systems.

In the abstract, it is easy to understand that there is a wide range of risks for the United States and the world population associated with continuing down the path of climate change. The challenge of going the next step toward summarizing and monetizing these costs—a necessary step for informing policy-makers—has only recently been addressed. In 2010, a government working group produced an estimate of the damages associated with the release of an additional ton of CO_2 in the atmosphere, which is referred to as the social cost of carbon (SCC). The conclusion of this analysis was that the current SCC or global damages from the release of an additional ton of carbon is roughly \$21 per ton of CO_2 emissions.[1] To put that in context, at a cost of \$21, carbon emissions in the United States last year resulted in roughly \$120 billion in damages. (See Box 1 for a discussion of some of the issues involved in making this calculation.) The damages within the United States are projected to be smaller, ranging from about 7 to 23 percent of the total. Of course, the global and domestic damages apply regardless of where the emissions occur in the planet.

With this estimate of the SCC, policy-makers now have a bright-line rule for identifying effective policies by enabling them to quantify the benefits of regulations that would reduce carbon emissions. In Table 1, we use the SCC to quantify the climate-related damages from various energy sources.

3. Other environmental and economic effects

The most significant environmental effect associated with the energy sources we currently rely on is climate change due to greenhouse gas emissions, but other aspects of energy production also impose significant costs.

Extracting, transporting, and consuming fuels such as coal and petroleum have adverse effects on the environment and impair our quality of life. The methods used to extract fuel, like coal mining or offshore oil drilling, can be very disruptive to the surrounding ecosystem. Strip mining, a form of surface mining that peels back layers of soil and rock to expose seams of mineral, destroys vegetation, displaces wildlife, and often permanently changes soil composition. The Deepwater Horizon oil spill in 2010, which damaged both local ecosystems and local economies, is one illustration of the consequences of accidents. Air pollutants, like those that form acid rain or airborne mercury from burning coal, have negative effects on trees, wildlife, ocean life, and soil quality. The smog that results from air pollutants impairs visibility and interferes with enjoyment of national parks and other scenic vistas.

Pollution also results in economic damages. Ozone can slow plant and crop growth and increase plants' vulnerability to disease (Mauzerall and Wang 2001; Reilly et al. 2007). Recent evidence suggests that ozone has a significant impact on the health and productivity of workers. Ozone, even at levels below Environmental Protection Agency (EPA) standards, has been shown to reduce the productivity of agricultural workers in California (Graff Zivin and Neidell 2011).

Even some "alternative" energy sources, some of which have been heralded as the future of energy use, have significant environmental costs. Biofuels such as ethanol were once considered a promising substitute for carbon-intensive fuels. However, growing, transporting, and processing the crops used for biofuels results in large emissions of CO_2. Examining the entire life cycle of production and consumption of biofuels suggests that they may actually be, on balance, worse for the environment than the entire energy cycle for oil.

4. Macroeconomic stability and international security

Energy security has been a critical concern for U.S. policy-makers since at least the oil shocks of the 1970s. Although U.S. oil intensity—the amount of oil the U.S. consumes per dollar of economic activity—has been declining by about 2 percent per year since 1980, our economy remains heavily dependent on oil (Sieminski 2010). In the transportation sector, there are almost no substitutes; oil provides more than 90 percent of U.S. fuel needs (NAS 2010). The consequence is that oil continues to play both a substantive and symbolic role in the economy. The challenges that arise from U.S. reliance on oil have both economic and geopolitical dimensions.

Dependence on oil imposes macroeconomic risks from oil shocks. Ten of the eleven postwar recessions followed an increase in the price of oil, including the most recent recession (Hamilton 2009b, 2011). While some research suggests that oil shocks have had steadily smaller effects on economic activity since the 1970s—perhaps because our economy's oil intensity has been diminishing, because policy-makers have learned how to respond better to these shocks, or because the U.S. economy is more flexible today than it was—evidence from the most recent recession suggests our vulnerabilities to oil shocks have not disappeared (Blanchard and Gali 2007, Hamilton 2009a).

Oil consumption also raises geopolitical and national security issues. For more than fifty years, the United States has maintained a military presence in the Persian Gulf. Although it is difficult to disentangle energy security from other national security goals, the need to guard against the possibility of oil disruptions has added urgency to U.S. military action. According to Brent Scowcroft, the national security adviser under President Gerald Ford and President George H. W. Bush, "What gave enormous urgency to [the Persian Gulf War] was the issue of oil" (Scowcroft 1996).

C. ESTIMATES OF PRIVATE AND SOCIAL COSTS OF VARIOUS ENERGY SOURCES

Smart energy policy must take into account the full costs of energy production. This includes the private costs of building, maintaining, operating, and fueling electricity generating plants or transportation vehicles, as well as the social costs to health and the environment. Making good energy policy decisions has been especially difficult because the exact extent of the private and social costs has not always been clear.

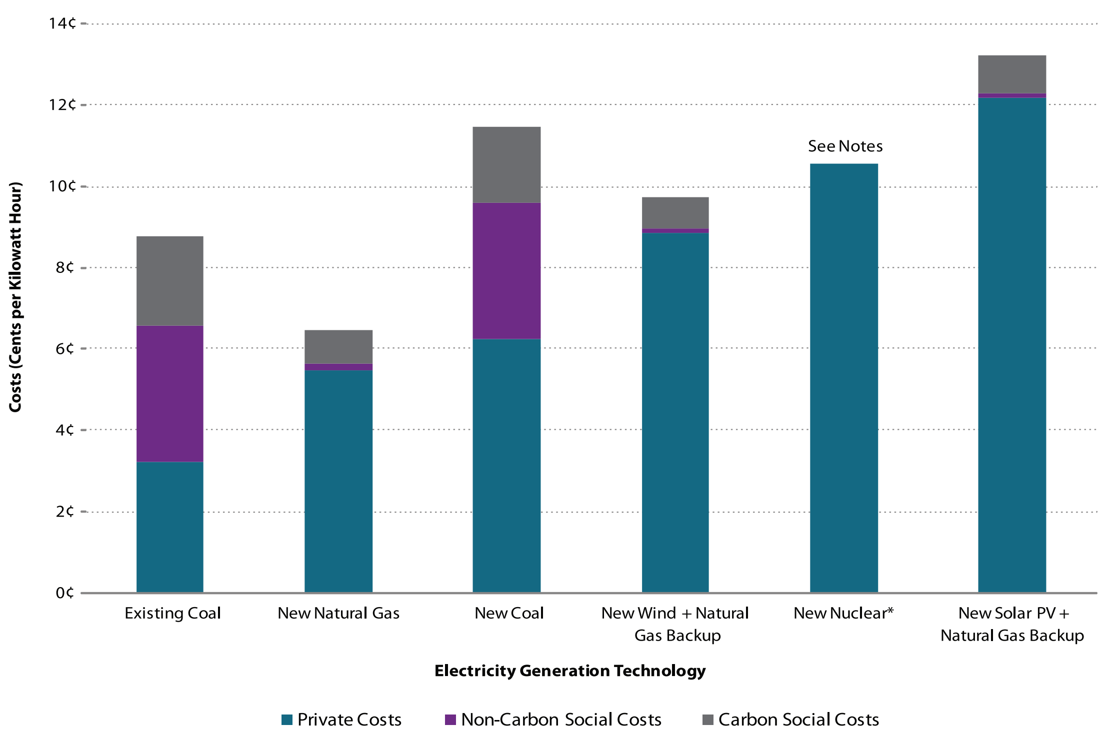
Indeed, without access to full, transparent information about the true costs of energy sources, policy-makers have not had the tools at their disposal to make the best choices for the economy and the welfare of the American people. By providing an "apples-to-apples" comparison of actual costs, we can help level the playing field among the various energy sources—providing more-accurate information for the public discussion around energy policy.

Table 1 provides new and what we believe are the best available estimates of the private, non-carbon social costs, and carbon costs of electricity production for several different energy-producing technologies, including coal, natural gas, nuclear, wind, solar, and hydroelectric. We are unaware of a previous effort to pull all of these cost components together.

Figure 6 summarizes several of the most important electricity sources from Table 1. These sources are shown in order of their private costs. The private costs are in blue, the non-carbon social costs—mostly health costs—are in purple, and carbon costs due to climate change are in gray. The dramatic differences in the private and social costs of different energy sources illustrate how the low private cost energy sources we rely on often come with high social costs.

FIGURE 6

Private and Social Costs of Electricity



Sources: Author's calculations; Du and Parsons (2009); EIA (2010b, 2010d, 2011a, 2011c, 2011d, 2011e, 2011f); Interagency Working Group on Social Cost of Carbon, United States Government (2010); Internal Revenue Service (2011); National Academy of Sciences (2010).

Note: Non-carbon social costs include only damages associated with operating the plant, not upstream costs from mining, drilling, or construction. *The non-carbon social costs of nuclear power, including the risk of serious accidents, have not been quantified for this figure.

BOX 2

The Private and Social Costs of Electricity Generation

Table 1 provides information on electricity generation focusing on the full life-cycle costs of creating new electricity generating capacity using different types of electricity sources—the total cost per unit of energy of starting up and operating a new plant over the entire lifetime of the plant (sometimes called the "levelized cost") including the health and environmental costs associated with electricity production. The table also provides estimates of the full costs of electricity from the three most important sources of existing generating capacity. These costs are divided into private costs—the cost of building, fueling, operating, and maintaining a plant; non-carbon social costs—primarily the costs to health; and carbon-related social costs due to climate change.[3]

Although we attempt to draw upon the best available data and research when producing these estimates, there is substantial uncertainty around many of these costs. For some energy sources, estimates of non-carbon social costs are difficult to quantify or are simply not available. For example, for nuclear and hydroelectric power, the non-carbon social costs from nuclear accidents or from damage to fisheries are very real, but few studies have reliably estimated those costs. Additionally, the prices of fuel sources are determined by market forces, and can rise or fall over time, leading to changes in private costs. Similarly, innovation has reduced the costs of many emerging technologies and may continue to reduce private costs in the future.

The fifth column shows estimates of the levelized private costs of generating electricity from different sources. For baseline power—power that is not subject to interruption—natural gas and coal are the least expensive sources of new electricity capacity when measured by private costs.

These private costs do not take into account the significant social costs stemming from many electricity sources. The sixth column shows the non-carbon social costs associated with different types of electricity sources, such as negative effects on health and the environment. Coal has high non-carbon social costs of 3.4¢/kWh—roughly the same size of its private costs for existing capacity and more than 50 percent of its private costs for new capacity. The next column shows the costs associated with carbon emissions, assuming an SCC of $21.4 per ton (the preferred estimate of the Interagency Working Group of the Social Cost of Carbon, United States Government [2010]).

The final column shows the total costs, including all private and social costs. The costs of several electricity sources increase dramatically when the full costs of production are included. For example, the total cost of existing coal plants more than doubles once the private costs are taken into account; the total cost of new conventional coal plants is roughly 83 percent higher than the private costs, making coal the most expensive new non-renewable source of energy. Conversely, for many other electricity producing technologies such as hydro, nuclear, wind, and solar, the private costs make up the vast majority of the total costs.

Estimates of the costs of "intermittent" energy sources—wind and solar—also must be adjusted to reflect the fact that they cannot be compared directly to those of base-loading technologies: wind power plants only produce power when there is wind and solar power plants only produce power when there is sunlight. Sunny and windy times of the day or year do not always correspond to times when demand for power is greatest. Consequently, these types of energy are less valuable even if the cost per kilowatt hour is the same as coal, natural gas, or other "dispatching" energy sources (sources that can be turned on and off to produce power when needed most). Similarly, cost estimates for "peaking" generating technologies such as natural gas combustion turbines overstate their costs because they are specifically designed to be used in times of very high demand for electricity.

To put these sources on comparable footing, we created hypothetical plants that include intermittent technologies paired with a "peaking" generating technology (natural gas combustion turbines) that could meet energy needs during periods when solar or wind power is unavailable. These estimates, which we label "Combined Peaking and Intermittent" in Table 1, suggest that some versions of these combined plants could be competitive with many existing technologies if the full social costs of energy production were taken into account. For example, the combined wind-combustion turbine power plant would have total costs almost 2¢ per kWh less than the total costs of new coal capacity. However, this combined wind-combustion turbine technology would still have significantly higher total costs than many other options, including new conventional natural gas power plants and existing coal power plants. Furthermore, the wind and solar estimates are based on siting plants in optimal locations for harvesting these energy sources; the cost estimates would be higher, potentially significantly so, in other locations.

When private costs alone are considered, existing coal power plants appear to be a great deal. These plants account for roughly 45 percent of the electricity in the United States, and they do so at a price of 3.2¢ per kWh. This appears to be a bargain, but the reality is that the true costs are much higher—in fact, they are 170 percent higher. The reason is that each kWh of coal-generated electricity comes with an additional 5.6¢ per kWh of damages to our well-being, due to 3.4¢ per kWh of non-SCC-related damages (primarily health) and 2.2¢ per kWh of climate change–related damages. Although these costs are not listed on our monthly utility bills, they are nevertheless real—they show up in shorter lives, higher health-care bills, and a changing climate that poses risks to our way of life.

Figure 6 also reports on the costs of other electricity sources. Electricity from new coal plants is more expensive, largely due to the capital costs of building the plant; because new plants are slightly cleaner, social costs are modestly lower. Once the full private and social costs of all energy sources are accounted for, natural gas power plants are among the least-expensive electricity sources. This reflects the low prices of natural gas due to the recent dramatic increase in reserves.

For vehicles and transportation, the story is similar. From sticker prices on new cars to the price at the pump, the private costs of transportation are readily apparent to most Americans. The private costs to purchase, maintain, and fuel the average car add up to about $0.51 per vehicle mile travelled over the car's lifetime (IRS 2010). But cars, trucks, and other vehicles also impose costs on others by polluting the air, emitting greenhouse gases, and contributing to traffic on busy roads, and through injuries and deaths from car crashes (Parry and Small 2005). In total, these social costs amount to more than $0.10 per vehicle mile travelled, or roughly $16,000 for a car that is driven 150,000 miles (Parry, Walls, and Harrington 2007)—which represents more than 20 percent of the car's lifetime private costs.

An additional consequence of the costs in Table 1 is that industry and consumers have little incentive to change their energy preferences based on comparison of direct costs. This is because coal and gasoline are comparatively inexpensive when only their private costs are considered.

In addition to the private and social costs of these energy sources, policies to influence energy production also consume significant fiscal resources. Table 2 details the many subsidies and financial incentives for different types of energy production provided by the federal government. The higher cost per kilowatt hour for some sources are frequently justified as efforts to jump-start the innovation necessary to drive down costs.

Although these costs are not listed on our monthly utility bills, they are nevertheless real—they show up in shorter lives, higher health-care bills, and a changing climate that poses risks to our way of life.

TABLE 1

Private and Social Costs of Electricity Generation

[1] Type	[2] Technology	[3] Capacity Factor[c] (percent)	[4] Share of Current Generation[d] (percent)	[5] Private Costs[e,f] (¢/kWh)	[6] Non-Carbon Social Costs[i,j] (¢/kWh)	[7] Carbon Emission Costs[k] (¢/kWh)	[8] Total Costs[m] (¢/kWh)
A. Existing Capacity[a]							
Fossil Fuels	Existing Coal	85	45	3.2	3.4	2.2	8.8
	Existing Natural Gas	87	24	4.9	0.2	1.0	6.0
Other Traditional	Existing Nuclear	90	20	2.2	Unable to Quantify	≈0	2.2
B. New Capacity[b]							
Base-Loading Technologies							
Fossil Fuels	Coal (Dual Unit Advanced PC)	85		6.2	3.4	1.9	11.5
	Natural Gas (Conventional Combined Cycle)	87		5.5	0.2	0.8	6.5
Other Traditional	Nuclear (PWR)	90		8.2-10.5[g]	Unable to Quantify	≈0	8.2-10.5
	Hydro	52		6.4	Unable to Quantify	≈0	6.4
Renewables	Geothermal	92		8.3	Unable to Quantify	0.1	8.4
	Biomass	83		9.5	Unable to Quantify	0.0-2.7[l]	9.5-12.1
Combined Peaking and Intermittent	Wind (Onshore) backed up with Natural Gas Combustion Turbine	85		8.9	0.1	0.8	9.7
	Solar (PV) backed up with Natural Gas Combustion Turbine	85		12.2	0.1	0.9	13.2
Peaking Generating Technologies							
Modified Traditional	Natural Gas (Conventional Combustion Turbine)	30		10.8	0.2	1.3	12.2
Intermittent Generating Technologies							
Renewables	Wind (Onshore)	34		8.0[h]	Unable to Quantify	≈0	8.0
	Wind (Offshore)	34		19.1[h]	Unable to Quantify	≈0	19.1
	Solar (PV)	25		19.5[h]	Unable to Quantify	≈0	19.5
	Solar (Thermal)	18		29.7[h]	Unable to Quantify	≈0	29.7

Sources: Author's calculations; Du and Parsons (2009); EIA (2010b, 2010d, 2011a, 2011c, 2011d, 2011e, 2011f); Interagency Working Group on Social Cost of Carbon, United States Government (2010); Internal Revenue Service (2011); National Academy of Sciences (2010).

PC = Pulverized Coal, PV= Photovoltaic, PWR = Pressurized Water Reactor.

Note: All dollar figures are 2010 US$. Values originally not reported in 2010 US$ are inflated using the CPI. A technical appendix available upon request includes a full description of the methodology and assumptions used to generate these estimates. Cost figures may not sum due to rounding.

Notes for Table 1

a. Estimates for existing coal, natural gas, and nuclear facilities assume the same fuel costs, and capacity factors as the new coal dual unit advanced PC, the new natural gas conventional combined cycle, and the new nuclear (PWR) plants, respectively. Existing plants are assumed to have two-thirds the operating, management, and maintenance costs of the corresponding new plants to reflect the fact that existing plants, on average, are subject to less stringent environmental standards and use older technologies. Existing plants are assumed to have fully depreciated all initial capital costs. To account for the fact that existing plants are, on average, less efficient than new plants, we use the estimated heat rates for existing plants in 2009 from EIA 2011d. The heat rates are 10,461 Btu/kWh for coal, 8,160 Btu/kWh for natural gas, and 10,460 Btu/kWh for nuclear.

b. These estimates do not include experimental technologies such as plants with carbon capture and sequestration or integrated gasification combined cycle plants.

c. Source: EIA 2011a.

d. Source: EIA 2011c.

e. Private cost estimates for new capacity are levelized costs: they reflect the present discounted value of the total cost of constructing, maintaining, and operating an electricity generating plant over its entire lifetime and expressed in terms of real cents per kilowatt-hour.

f. Authors' estimates based on a model developed by Du and Parsons (2009). Most cost inputs for new capacity, including overnight capital costs, operation and management costs, and heat rates come from EIA 2010b. Fuel price estimates for coal and natural gas come from 2011e, while fuel price estimates for nuclear power come from 2011f, and those for biomass come from 2010d. All plants are assumed to have identical forty-year lifetimes. Estimates for new capacity refer to plants coming on line in 2017 to compensate for the significant lead time required to construct many types of new plants.

g. Range reflects alternative financing costs. The low end of the range assumes a weighted average cost of capital of 7.8 percent (the same as the assumption for all other technologies), while the high end of the range assumes a weighted average cost of capital of 10 percent. This approach follows MIT (2003) and Du and Parsons (2009). The capital cost estimates from EIA 2010b assume that the nuclear plant is built in a Brownfield site. Greenfield sites may be more expensive.

h. Estimates for wind and solar are based on current market costs, which have been declining due to advances in technology. Some analysts argue that improved technology will substantially reduce the price of wind and solar power. For example, if overnight capital costs of solar PV were reduced to $2,000/kilowatt, levelized costs for solar PV would drop to 8.6¢/kWh.

i. Source: NAS 2010, p. 92 (coal) and p. 118 (natural gas). The NAS estimates the monetized costs resulting from emissions of SO_2, NO_x, $PM_{2.5}$, and PM_{10} from existing natural gas and coal power plants, assuming a value of a statistical life of $6 million (2000 US$). These estimates do not include social costs other than from those four air pollutants, nor do they include "upstream" social costs resulting from mining, drilling, construction, and other activities not directly associated with electricity generation. While it is likely that new plants are more efficient, the assumption that both existing and new plants have the same social cost reflects the fact that both existing and new plants are included under the same SO_2 and NO_x cap-and-trade cap.

j. Reliable estimates of the non-carbon social costs are unavailable for many electricity generation technologies, even for technologies like nuclear or hydroelectric that have demonstrable environmental or health costs. We label non-carbon social costs of these technologies "unable to quantify."

k. Source: tCO_2/Btu or tCO_2/MWh from EIA 2010b; social cost of carbon $22.5/$tCO_2$ (2010 dollars) from the Interagency Working Group on Social Cost of Carbon, United States Government (2010).

l. The range of carbon emissions estimates reflects uncertainty regarding the source of biomass fuel materials.

m. Intermittent energy sources, such as wind and solar, only produce power during periods of sufficient wind and sunlight. The costs in this table do not attempt to monetize the reduction in value that this intermittency imposes on energy users. On adjusted basis, wind and solar would be more costly. Conversely, peaking generating technologies, such as natural gas combustion turbines, are used only during periods of fluctuating high demand, and thus appear expensive in this comparison. For a more detailed discussion, see Joskow (2010). In an attempt to define a more appropriate comparison of wind and solar to other base-loading technologies, "Combined Peaking and Intermittent" presents estimates of hybrid wind and solar PV facilities that are backed up by natural gas combustion turbine during periods of intermittency. These hypothetical plants assume a renewable source is paired with a natural gas combustion turbine of sufficient capacity such that the natural gas combustion turbine could fully substitute for the renewable source if it produced no output during some time periods. The average capacity factor of the paired natural gas combustion turbine is chosen such that the average capacity factor for the combined plant is equal to 85 percent (roughly the capacity factor for traditional coal and natural gas combined cycle plants).

TABLE 2

Federal Energy Subsidies

Type	FY 2007 Net Generation (billion KWh)	Federal Subsidy and Support Value 2007 (million dollars)
Coal	1,946	854
Refined Coal	72	2,156
Natural Gas and Petroleum Liquids	919	227
Nuclear	794	1,267
Biomass (and biofuels)	40	36
Geothermal	15	14
Hydroelectric	258	174
Solar	1	14
Wind	31	724
Landfill Gas	6	8
Municipal Solid Waste	9	1

Source: Table 35, EIA (2008)

Other government programs also give a leg-up to preferred energy sources. Liability for nuclear disasters is capped at $12.6 billion and oil companies' responsibility for spills is capped at $350 million for onshore facilities and $75 million for offshore facilities (EPA n.d.; Nuclear Regulatory Commission [NRC] 2010). Thus, these energy producers are protected from the risks they impose on everyone else, liabilities that other businesses are required to shoulder (Greenstone 2010). Additionally, federal and state legislation has granted a host of subsidies for ethanol production and use, including a tax credit equal to $0.45 per gallon for blending ethanol with other fuels and a variety of other standards that require the use of ethanol (DOE n.d., EPA 2010a; Rudolf 2010). These subsidies impose a substantial fiscal cost on taxpayers while creating market distortions.

Efforts to address the environmental, health, and climate-related effects of our current energy sources are often derided as too costly. But Table 1 emphasizes that many of our current energy sources are already more costly than perceived—those costs are simply more diffuse and less salient because they indirectly impact health, economic activity, the environment, and national security. Although there are undoubtedly costs associated with moving to energy sources that require higher private outlays, the introduction of policies that cause producers of all energy sources to recognize the full (private plus social) costs will level the playing field and improve our well-being.

For example, recent EPA analyses indicate that the benefits of recently proposed policies to address climate change would have exceeded their costs. The analysis suggests cumulative domestic costs of a cap-and-trade bill at $600 billion to $1 trillion through 2050 (Greenstone 2010). But the global cumulative benefits of the emissions reductions produced by enacting a cap-and-trade system would be approximately $1.5 trillion to $1.7 trillion over the same period, indicating that the benefits were much larger than the costs. Although a substantial proportion of these benefits would accrue outside the United States, many believe that the adoption of such a carbon policy would lead other countries to implement similar policies to reduce carbon emissions that would produce substantial benefits for the United States.

A fundamental change in our energy policy will not be easy and will come with costs, with some industries and regions in the U.S. economy being affected more than others. This is because U.S. households and businesses have made decisions based on the expectation of access to energy sources with relatively low direct costs. Furthermore, the costs of transitioning to energy sources with smaller social costs will be incurred in the present. The non-carbon benefits would begin to appear immediately, but the gains from slowing climate change would emerge more gradually over time.

Time and time again, the United States has risen to great challenges. The implementation of new energy policies that produce a full, transparent accounting of the social costs of all energy sources will require a shift in the way we do business in the United States. Meeting this challenge will require strong political will, but offers the promise of a future of healthier and longer lives, an improved environment, and greater national security.

We introduce below four Hamilton Project principles to provide guidance on a new energy policy to meet the challenges confronting our nation.

Chapter 3: Principles

The United States faces a fundamental choice: we can continue to rely on current energy sources that have relatively low out-of-pocket expenses but high hidden social costs, or we can begin the process of rebalancing our energy use so that all energy sources can compete on a level playing field. This will involve efforts on four fronts: (1) pricing carbon and other externalities appropriately so that consumers, firms, and producers have an incentive to make informed decisions about energy use while developing ways to mitigate the effects of energy price increases for low-income families; (2) ramping up funding for basic research, development and demonstration (RD&D) to lay the foundation for technology innovations, which will be critical to developing alternative energy sources and lowering the risks of energy sources we currently rely on; (3) making regulations more efficient; and (4) addressing climate change on a global scale. These principles provide the basis for moving toward a future that takes into account the full costs associated with our energy use:

A. APPROPRIATELY PRICE THE SOCIAL COST OF ENERGY PRODUCTION AND USE

Almost all energy sources have significant social costs that are not reflected in their prices but nonetheless have a real impact on well-being—not just in the United States, but globally. These costs include the economic and geopolitical consequences of reliance on oil, the pollution and changes in climate patterns that result from burning high-carbon fuels, the health effects of pollutants, and the risk of major accidents.

Pricing energy sources—carbon and oil in particular—to more fully reflect their social costs would give firms and consumers a strong incentive to change their energy consumption patterns and make better-informed decisions. Pricing also would give firms an incentive to research and invest in low-carbon technology and alternative fuels, helping to pave the way for a low-carbon future. Furthermore, policy-makers would have more-accurate information when making energy policy that helps guide production and consumption patterns in the United States.

Economists generally agree that pricing carbon using a market-based approach, through a carbon tax or cap-and-trade system, as opposed to regulation, is the most cost-effective way to reduce carbon emissions. The government has little way of knowing which firms and consumers could reduce their carbon emissions at the lowest cost and how they can do so. Firms and consumers are best-positioned to make these decisions, provided that they have an incentive to do so. Pricing carbon provides this incentive.

Because carbon pricing may disproportionately affect low-income households, who spend a greater percentage of their income on energy, as well as firms and industries that rely on carbon-intensive energy sources, it is critical to address any distributional consequences arising from new environmental policies.

1. Carbon tax

Like any other tax designed to curb activities that impose social costs, the ideal carbon pricing system would increase the cost of a carbon-based energy source so that it is in line with the true SCC, including both private costs and costs on others. By pricing carbon-emitting energy sources more

The United States faces a fundamental choice: we can continue to rely on current energy sources that have relatively low out-of-pocket expenses but high hidden social costs, or we can begin the process of rebalancing our energy use so that all energy sources can compete on a level playing field.

appropriately, firms and individuals would have the right incentive to reduce emissions to the optimal level.

In "A Proposal for a U.S. Carbon Tax Swap: An Equitable Tax Reform to Address Global Climate Change," Gilbert E. Metcalf, an economist at Tufts University, has proposed a carbon tax that would start at $15 per ton of CO_2 and gradually increase to give the economy time to adjust (Metcalf 2007). The tax would be imposed "upstream" at the producer level, which would allow for easier monitoring and economy-wide coverage. Metcalf estimates that the tax would reduce greenhouse gas emissions by 14 percent and initially raise $82.5 billion. He argues that this revenue should be used for a "carbon tax swap" that counters the regressive impact of higher energy prices by funding a payroll tax reduction. Under his proposal, all workers would be given a refundable income tax credit equal to their 15.3 percent payroll tax up to a maximum credit of $560.

A carbon tax has several strengths, foremost of which are price certainty and ease of implementation. Price certainty is important for firms, which need to have a predictable economic environment in order to invest. A carbon tax would be relatively easy to implement because it would be administered through the existing tax system. The weakness of this approach is that the tax would raise energy prices in a visible way, even though the money goes back in consumers' pockets through the tax credit. Given that there is currently no political appetite for new taxes, the likelihood of implementation in the near future is limited.

Compared to a carbon tax or a cap-and-trade system, the National Clean Energy Standard would be a more incremental approach to pricing carbon… it would represent a modest adjustment and harmonization of regulations (e.g. renewable portfolio standards) that already exist in many states.

2. Cap-and-Trade

Another way to price carbon, which yields the same environmental outcomes as a carbon tax, is a cap-and-trade system. In a standard cap-and-trade system the government establishes a cap on total emissions by issuing a limited number of permits and requiring firms to hold a permit for each unit of carbon they emit. The permits would be tradable, enabling firms that can reduce their emissions at a low cost to sell permits to firms that can only reduce emissions at a high cost. A market would thus be established that places a price on pollution.

In "A U.S. Cap-and-Trade System to Address Global Climate Change," Robert Stavins, an economist at Harvard University's John F. Kennedy School of Government, has proposed a cap-and-trade system with a number of distinct features (Stavins 2007). Half of all permits would initially be issued to current energy producers and half auctioned off. In his plan, the emissions cap gradually tightens, resulting in stable atmospheric CO_2 concentrations of 450–550 ppm. To reduce cost uncertainty, Stavins suggests allowing firms to bank and borrow permits. If the price of permits exceeded a specified level, the government would be allowed to issue more permits. Like Metcalf's tax, Stavins' proposed cap-and-trade system would use revenue from auctioned permits to mitigate the regressive impact of higher energy prices. It also would initially allocate some fraction of permits for free to firms that would be particularly affected, gradually increasing the proportion sold at auction.

The main advantage of a cap-and-trade system is the ability to set and meet a particular emissions target. Furthermore, cap-and-trade has also worked well in the past, notably with sulfur dioxide after the passage of the 1990 Clean Air Act amendments and phasing out leaded gas in the 1980s (Stavins 2001).

3. A National Clean Energy Standard

In a new discussion paper for The Hamilton Project, "Promoting Clean Energy in the American Power Sector," Joseph Aldy of Harvard University's John F. Kennedy School of Government (2011) proposes the establishment of a national clean energy standard that applies to the power sector, which is the nation's largest source of CO_2 emissions, producing 30 percent of the total. The standard would be technology-neutral to enable all energy sources to play a role and to spur innovation. It would also be based on the amount of CO_2 produced per unit of electricity, initially requiring power plants to achieve a standard of 0.4 tons of CO_2 emissions per megawatt hour (MWh) of electricity generated. The standard would become more stringent over time, requiring a 50 percent reductions in emissions per MWh by 2035.

Power plants could meet the standard in one of three ways, by (1) producing all their power at or below the threshold, (2) by buying credits from power plants that beat the standard, or (3) by buying federal credits at a price starting at $15 per ton of CO_2 in 2015. The combination of ambitious, "stretch" performance goals and the option to purchase federal credits at a preset price would result in price certainty—businesses would know that the price of clean energy credit in 2015 would be $15, and they would know how this price will increase over time. This certainty about revenue streams for clean energy would facilitate more project finance and lead to more investment. Aldy estimates that his proposed national clean energy standard would lower power sector CO_2 emissions about 15 percent below 2005 levels by 2020.

Aldy proposes that the first $2 billion in revenue that is generated from the selling of energy credits would be used to fund basic energy R&D and technology demonstration. Any remaining revenue could be used for deficit reduction or tax cuts, such as lower payroll taxes, perhaps targeted to mitigate the regressive effect of rising energy prices.

Compared to a carbon tax or a cap-and-trade system, the National Clean Energy Standard would be a more incremental approach to pricing carbon. This is in many respects a strength of the proposal. The standard would apply to one critical sector of the economy instead of being applied economy-wide, and could thus serve as a "test case" for pricing carbon. The national standard also would stop short of introducing an entirely new system. Instead, it would represent a modest adjustment and harmonization of regulations (e.g. renewable portfolio standards) that already exist in many states.

B. FUND BASIC RESEARCH, DEVELOPMENT AND DEMONSTRATION

Developing new technological innovations in energy will be critical if we hope to reach a cleaner energy future. However, the private sector may underinvest in basic R&D, even in the presence of a carbon price. Basic research involves spillovers, so that the benefits of RD&D may not accrue to the pioneering firm but to other firms and to consumers. Because firms cannot capture all the benefits of their innovations, they do not have the incentive to fund the basic research necessary to achieve a clean energy future.

Research into new technologies is particularly unrewarding in the absence of a price on carbon. Without certain and dependable policies raising the price of emitting carbon, there is little incentive for firms to innovate carbon-reducing technologies. A number of studies, moreover, indicate that policies targeting energy RD&D and emissions pricing can reduce carbon emissions more cost-effectively than emissions pricing alone (see Congressional Budget Office [CBO] 2006; Fischer and Newell 2007; Goulder 2004).

The public good nature of RD&D—where the benefits are broadly shared by everyone—means that the government must have a leading role in critical areas where the private sector is unable or unwilling to step in. Federal energy RD&D investments have been very productive. A recent study of twenty-nine DOE-sponsored RD&D programs in energy efficiency and fossil energy found that these programs, taken together, yielded annual rates of return of more than 100 percent (NRC 2001).

Despite the extremely high returns to RD&D spending, the federal government spends less on energy RD&D today than it did three decades ago, both in absolute terms and as a percentage of GDP. In 2009, the government spent $1.7 billion on energy RD&D. In constant dollar figures, this is less than one-fourth of what the government spent in the 1980s, and as a percent of GDP, it amounts to less than one-tenth of peak spending in 1979 (OMB 2010). This spending was increased as part of the American Recovery and Reinvestment Act of 2009 but is projected to decline again as that Act's provisions expire.

It is clear that we can do better. In addition to pricing carbon, principles of a federal energy RD&D policy moving forward should include increasing funding, ensuring political independence, focusing on basic research, developing new RD&D funding mechanisms, and supporting demonstration rather than deployment.

1. Increased funding

Funding for federal energy RD&D should be ramped up in order to accelerate the process of developing alternative energy sources and establishing the commercial viability of new technologies that would lower the cost of alternative energy sources and mitigate the risks associated with current sources.

2. Political independence

As funding mechanisms at the National Institute for Health (NIH) and the National Science Foundation (NSF) have demonstrated, one of the keys to successful RD&D policy is awarding funds based on merit through a competitive, peer-reviewed process that ensures maximum value for RD&D spending.

3. Focusing on basic research

As discussed above, the private sector lacks adequate incentives to invest in RD&D because either the resulting benefits accrue widely or commercial application is uncertain.

The government should maintain focus on basic RD&D and keep out of the business of picking winners and losers.

4. Developing new RD&D funding mechanisms

Some funding mechanisms are preferable and more likely than others to achieve certain desired outcomes. The use of prizes, for example, can be more effective than grant awards in achieving defined goals because they award outcomes and accomplishments.

5. Demonstrate commercialization potential

They government can overcome barriers faced by the private sector by taking the lead on technology demonstration, a critical step in the innovation process that generates information on the commercial viability of a new technology. To avoid mistakes of the past, federal energy RD&D funds should be used for demonstration, not deployment. Specifically, government demonstration funding should be limited to new energy technologies with the limited purpose of providing information to private sector investors about the technical performance, economic costs, and environmental effects of various technology options. These cases arise only when firms that do not invest in demonstration stand to appreciably learn from it.

In a new discussion paper for The Hamilton Project, John Deutch (2011) of the Massachusetts Institute of Technology proposes a number of reforms in the way technology demonstration projects are selected, designed, and managed that would facilitate the spread of critical information to firms and speed the pace of innovation. Demonstration is the key step of building a prototype or practical example of a new technology that bridges the gap between the R&D phase and deployment of the technology at a commercial scale. In his paper, "An Energy Technology Corporation Will Improve the Federal Government's Efforts to Accelerate Energy Innovation," Deutch proposes creating a semi-public organization called the Energy Technology Corporation (ETC) that would supervise and execute technology demonstration projects. The reforms he calls for include identifying clear objectives for technology demonstration, developing a modeling or simulating capacity to evaluate the promise of alternative demonstration projects, involving knowledgeable private sector experts in the process, and developing metrics to track the effectiveness of different demonstration efforts.

Essential elements of the ETC would include emphasis on creating options through demonstration, not deployment; commercial rather than government-based project management; involvement of individuals with technical and financial experience in the private sector; and freedom from the congressional authorization and appropriation cycle.

C. MAKE REGULATIONS MORE EFFICIENT

Steps to fully price different energy sources should be the linchpin of energy policy moving forward. However, regulation will continue to play an important role in policy-making; therefore, the goal should be to make regulations as efficient and cost-effective as possible without compromising appropriate protections for human health and the environment.

There is currently much controversy around EPA's regulatory structure—some say it is too far-reaching, and some say it imposes unnecessary costs on American businesses and consumers. One reaction is to call for diminishing the role of EPA's regulatory authority. However, this approach could foreclose the opportunity to benefit Americans in ways that some previous EPA regulations have. For example, the Clean Air Act of 1970 led to reductions in particulate air pollution, which lowered infant mortality rates (Chay and Greenstone 2003b); declines in ozone concentrations (Henderson 1996); and reduced health-care costs and the incidence of premature mortality (Deschenes et al. 2011).

A preferred option is to use sound evidence and rigorous CBA to ensure that regulations carefully weigh the health and environmental benefits of pollution-reducing rules against their economic costs. Effective environmental regulation should use rigorous CBA to advance only those regulations where benefits clearly outweigh costs. As a tool for making decisions, CBA has obvious advantages. But in practice, it can be a challenging exercise that requires difficult choices and involves relying on uncertain information.

In his new discussion paper for The Hamilton Project, "A Better Approach to Environmental Regulation: Getting the Costs and Benefits Right," Ted Gayer (2011) of The Brookings Institution argues that the process of applying CBA needs to be more rigorous and more systematic. First, Gayer proposes a checklist of best practices that regulators can use to assess which empirical studies are reliable and compelling. Currently, regulatory guidelines give little guidance on how to assess the credibility of different studies. Consequently, highly credible studies are treated similarly to less-credible studies during the regulatory process. This practice hurts regulatory quality because figuring out the effect of different regulations is tricky and the credibility of empirical studies varies widely.

Climate change is distinct from many environmental and energy-related challenges in that it is global in scope.

Implementing his suggested checklist would improve many regulations by ensuring that decisions are based on only the most credible empirical research.

Second, Gayer suggests excluding private benefits to consumers in CBA of regulations such as fuel and energy efficiency standards. These benefits currently are assumed to arise through regulations that narrow the "energy-efficiency gap," which is the empirical finding that consumers appear to overlook cost-effective investments in energy efficiency. Traditional CBA would assume that this gap is illusory—consumers have different preferences and simply must prefer the less-efficient product for reasons the regulator does not observe (i.e., they prefer a less-efficient top-loading washing machine because they place a high value on its convenience or a larger car because it helps with carpooling). An alternative view, motivated by the observation that consumers deviate from "rational" economic behavior in certain circumstances, is that this energy-efficiency gap reflects a lack of information or other oversight on the part of the consumer.

Increasingly, CBAs have taken the energy efficiency gap at face value and have counted the value of improving energy efficiency as a benefit to consumers themselves. For example, 88 percent of the gross benefits from the new Corporate Average Fuel Economy standards come not from environmental benefits, but from consumers themselves saving on fuel, time spent refueling, and increased driving. Gayer argues these are features that consumers observe and can judge for themselves, and that there is little evidence that consumers systematically underestimate the benefits of energy efficiency. And even if they did, it is unclear whether regulators could do better as they presumably suffer the same biases and information problems as consumers. Consequently, Gayer proposes that CBA exclude these private benefits to consumers from energy efficiency standards unless a specific market-failure can be documented that causes individual consumers to make poor choices.

Finally, Gayer proposes establishing an early review process at the Office of Information and Regulatory Affairs (OIRA), the Office of Management and Budget's (OMB) office that oversees the regulatory process, for particularly significant regulations. Currently, many regulations are submitted to OIRA in near final form with limited time for OIRA to respond. This undermines the regulatory process and makes it difficult for CBA to become an input to decision-making rather than a rubber stamp. This six-month early review process would allow both OIRA and the public sufficient time to analyze proposed rules and implement Gayer's proposed checklist. This early-review process would only apply to regulations with estimated economic impacts of $1 billion or more plus selected additional rules identified by the OIRA director (roughly twenty in total per year). The greater scrutiny and analysis of these proposed regulations also will make them easier to analyze after implementation, increase understanding of the impacts of different regulations, and provide information to improve future CBAs of proposed regulations.

D. ADDRESS CLIMATE CHANGE ON A GLOBAL SCALE

Climate change is distinct from many environmental and energy-related challenges in that it is global in scope. A ton of CO_2 released in Beijing, London, or Lagos has the same climate impact on the United States as a ton of CO_2 released in Pittsburgh or Los Angeles. While there is little dispute over the global nature of climate change, a key sticking point in climate negotiations is whether developed countries or developing countries ought to bear responsibility for reducing carbon emissions.

One impediment to negotiations is that different nations have different views on the importance of reducing carbon emissions. From one perspective, many developed countries such as the United States are likely to value carbon reduction more highly, given that they already enjoy high average standards of living and wish to "insure" their prosperity. Developing countries, on the other hand, are likely to place less value on carbon reduction because they are more interested in economic growth (Becker, Murphy, and Topel 2010).

Developed countries have argued that the bulk of emissions growth projected to occur over the next several decades—three-fourths, in fact—will come from developing countries, China and India in particular, as they industrialize. Many of the lowest-cost opportunities to reduce emissions are also to be found in developing countries because their infrastructure is still in the process of being built and would generally not require costly retrofitting. Developing nations argue that developed countries are largely responsible for the precarious environmental situation the world finds itself in today, given that they produced their share of pollution as they industrialized. Developing nations also argue that it is unfair for developed countries to prioritize the environment over economic growth, given that they already enjoy high standards of living.

A strong U.S. role is necessary to bridge this divide and jump-start negotiations. As a leading emitter, it appears unlikely that other nations will engage in serious efforts to restrict greenhouse gas emission unless the United States joins these efforts. Leading by example does not mean implementing drastic cuts in emissions unilaterally—indeed, such an approach would be foolish and most likely ineffective. Several studies have cited the phenomenon of carbon leakage, noting that, in a world where only some countries regulate carbon, businesses would simply relocate to countries where carbon is not regulated as strictly (Aldy, Barret, and Stavins 2003; Weyant and Hill 1999).

One approach, which the European Union has pioneered, is to initiate modest reductions in carbon emissions and pledge to ratchet these up if other countries follow ("EU leaders agree on ambitious plan to battle global warming," 2007). Another approach is to reduce carbon emissions and then subject imports from non-carbon regulating countries to a carbon tax. Including the world's major emitters in efforts to counter climate change is, at any rate, essential to making progress on this issue and avoiding a central weakness of the 1997 Kyoto Protocol.

The next round of climate change negotiations will take place late in the fall of 2011 in South Africa to, among other items, discuss prospects for a legally binding agreement including all major emitting countries. However, there are steps that could be taken now with relative ease to help create the foundation for such an agreement.

As one example, with any multi-country agreement, accurately monitoring the progress of the other countries in meeting agreed-upon goals is crucial to domestic buy-in of that agreement. For example, if two countries agree to reduce carbon emissions by a certain amount over an agreed-on timeline, each country will be skeptical of results verified through a hand-shake. Developing and sharing the technology to accurately measure and monitor carbon emissions will play a central role in creating much-needed trust around climate change targets.

Recent climate change conferences have emphasized the importance of "Measurable, Reportable, and Verifiable" actions to shore up trust. Last year, in addition, India's Minister of Environment and Forests proposed a system of "International Consultations and Analysis" that would apply to developing countries. Revitalizing NASA's network of climate satellites, which provide critical data on the world's climate system, would be a concrete step toward promoting transparency in efforts to counter climate change. Climate satellites are critical to monitoring climate change because they provide globally consistent data, including data from important, but hard-to-access areas. They can be used to measure greenhouse gases and could serve as an early warning system for climate tipping points. Satellites also can be used to enforce commitments from countries that have agreed to reduce carbon emissions. Under the Kyoto Protocol, almost forty industrialized countries will be reporting their emissions against targets between 2008 and 2012. NASA's current network of satellites is aging, however. Of the nineteen climate satellites that are currently operational, half will have outlived their design life over the next eight years (Lewis, Ladislaw, and Zheng 2010).

Revitalizing NASA's network of climate satellites, which provide critical data on the world's climate system, would be a concrete step toward promoting transparency in efforts to counter climate change.

Chapter 4: Conclusion

The goal of our energy and climate policy must be to improve Americans' well being. Currently, the United States' energy policies tilt the playing field so that energy choices are largely based on the immediately visible costs that appear on utility bills and at the gas pump. The result is that we rely on energy sources that unnecessarily shorten our lives, raise our healthcare bills, contribute to changes in climate that pose risks to our way of life, and weaken our national security.

The most direct and efficient way to improve our energy policy is to price carbon and other pollutants appropriately, so that firms and consumers recognize the full costs of all energy sources. But other measures—greater investment in basic RD&D, efficient regulation, and a global framework for addressing climate change—are also necessary to maximize the benefits of our energy-driven economy.

Transitioning to a new energy future will not be easy. However, without a change to the rules of the road in energy production and consumption, we will undermine our well being and harm our children's future.

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Endnotes

1. The $21 figure is the central value and the U.S. government also recommended conducting sensitivity analyses at $5, $35, and $65. See Interagency Working Group on the Social Cost of Carbon, United States Government, 2010.

2. This process was convened by the Council of Economic Advisers and the Office of Management and Budget, with regular input from other offices within the executive office of the president, including the Council on Environmental Quality, National Economic Council, Office of Energy and Climate Change, and Office of Science and Technology Policy. Agencies that actively participated included the Environmental Protection Agency, and the Departments of Agriculture, Commerce, Energy, Transportation, and Treasury. For more information on how the SCC values were developed, see Greenstone et al. 2011.

3. Energy is usually measured in kilowatt hours, which is equal to the amount of energy consumed by a 100-watt light bulb if turned on for ten hours.

References

Abt Associates. 2004 (June). "Power Plant Emissions: Particulate Matter-Related Health Damages and the Benefits of Alternative Emission Reduction Scenarios." Report for Clean Air Task Force. http://www.abtassociates.com/reports/Final_Power_Plant_Emissions_June_2004.pdf.

Aldy, Joseph E. 2011 (May). "Promoting Clean Energy in the American Power Sector." Discussion Paper 2011-04, The Hamilton Project, Washington, DC.

Aldy, Joseph E., Scott Barrett, and Robert N. Stavins. 2003. "Thirteen Plus One: A Comparison of Global Climate Policy Architectures." *Climate Policy* 3(4): 373–97.

Almond, Douglas, Lena Edlund, and Marten Palme. 2009. "Chernobyl's Subclinical Legacy: Prenatal Exposure to Radioactive Fallout and School Outcomes in Sweden." *Quarterly Journal of Economics* 124 (4).

Becker, Gary S., Kevin M. Murphy, and Robert H. Topel. 2010 (September, rev.). "On the Economics of Climate Policy." Prepared for a conference on "Energy Policy and the Economy" jointly sponsored by the University of Chicago, Resources for the Future, and the University of Illinois.

Blanchard, Olivier, and Jordi Gali. 2007 (September). "The Macroeconomic Effects of Oil Price Shocks: Why are the 2000s so different from the 1970s?" Working Paper 13368. National Bureau of Economic Research.

Chay, Kenneth and Michael Greenstone. 2003a (August). "The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced by a Recession." *Quarterly Journal of Economics* 118 (3).

Chay, Kenneth and Michael Greenstone. 2003b (October). "Air Quality, Infant Mortality, and the Clean Air Act of 1970." Working Paper 04-08. MIT Department of Economics.

Chen, Yuyu, Avraham Ebenstein, Michael Greenstone, and Hongbin Li. 2011. "The Long-Run Impact of Air Pollution on Life Expectancy: Evidence from China's Huai River Policy." Working Paper.

Congressional Budget Office (CBO). 2006 (September). "Evaluating the Role of Prices and R&D in Reducing Carbon Dioxide Emissions." Washington, DC.

Currie, Janet, Eric Hanushek, E. Megan Kahn, Matthew Neidell, and Steven Rivkin. 2009. "Does Pollution Increase School Absences?" *The Review of Economics and Statistics* 91 (4). Cambridge, MA: MIT Press, vol. 91(4): 682–694.

Denning, Liam. 2010 (September). "Power Investing: There's a lot of money to be made—and lost—in the energy markets. Here's what you need to know." *Wall Street Journal*. http://online.wsj.com/article/SB10001424052748703846604575447762301637550.html#

Deschenes, Olivier, and Michael Greenstone. 2007 (August). "Climate Change, Mortality, and Adaptation: Evidence from Annual Fluctuations in Weather in the U.S." MIT Joint Program on the Science and Policy of Global Change. Report No. 153. MIT, Cambridge, MA.

Deschenes, Olivier, Michael Greenstone, and Joseph Shapiro. 2011. "Defending Against Environmental Insults: Drugs, Emergencies, Mortality and the NOx Budget Program Emissions Market," Working Paper.

Deutch, John. 2011 (May). "An Energy Technology Corporation Will Improve the Federal Government's Efforts to Accelerate Energy Innovation." Discussion Paper 2011-05, The Hamilton Project, Washington, DC.

Department of Energy (DOE), n.d. "Volumetric Ethanol Excise Tax Credit (VEETC)." Author, Washington, DC. Accessed at http://www.afdc.energy.gov/afdc/laws/law/US/399.

Du, Yangbo, and John E. Parsons. 2009 (May). "Update on the Costs of Nuclear Power." Working Paper 09-004. MIT Center for Energy and Environmental Policy Research. http://web.mit.edu/mitei/docs/spotlights/nuclear-fuel-cycle-du.pdf.

Energy Information Administration (EIA). 2008 (April). "Federal Financial Interventions and Subsidies in Energy Markets: 2007." http://www.eia.doe.gov/oiaf/servicerpt/subsidy2/.

Energy Information Administration (EIA). 2009a. "Energy Consumption, Expenditures, and Emissions Indicators, Selected Years, 1949–2009." Table 1.5. *Annual Energy Review 2009*.

Energy Information Administration (EIA). 2009b (November). International Energy Statistics database (as of November 2009). www.eia.gov/emeu/international.

Energy Information Administration (EIA). 2010a. "Shares of world energy consumption in the United States, China, and India, 1990–2035." Figure 14. *2010 International Energy Outlook*. http://www.eia.doe.gov/oiaf/ieo/world.html.

Energy Information Administration (EIA). 2010b (November). "Updated Capital Costs for Electricity Generating Plants." http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf.

Energy Information Administration (EIA). 2010c. "World Marketed Energy Consumption." Figure 12. 2010 International Energy Outlook. http://www.eia.doe.gov/oiaf/ieo/world.html.

Energy Information Administration (EIA). 2010d (June). "Consumption Price and Expenditure Estimates, State Energy Data System (SEDS)." Table S6a. Accessed at http://www.eia.gov/states/hf.jsp?incfile=sep_sum/plain_html/sum_pr_eu.html.

Energy Information Administration (EIA). 2011a. "Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011." http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html.

Energy Information Administration (EIA). 2011b (April). Annual Energy Outlook 2011. http://www.eia.gov/forecasts/aeo/.
Energy Information Administration (EIA). 2011c (April). “Monthly Energy Review, Table 7.2a. Electricity Net Generation: Total (All Sectors)”. Accessed at http://www.eia.doe.gov/totalenergy/data/monthly/query/mer_data.asp?table=T07.02.
Energy Information Administration (EIA). 2011d (rev. April). “Electric Power Annual,” Table 5.3. Accessed at http://www.eia.doe.gov/cneaf/electricity/epa/epat5p3.html.
Energy Information Administration (EIA). 2011e (April). “Electric Power Monthly.” Table 4.10.A and 4.13.A. Accessed at http://www.eia.doe.gov/electricity/data.cfm#avgcost.
Energy Information Administration (EIA). 2011f (April). “Updates by Energy Source, State Energy Data System (SEDS).” Table F23. Accessed at http://www.eia.gov/states/hf.jsp?incfile=sep_fuel/html/fuel_nu.html.
Environmental Protection Agency (EPA n.d.). “Oil Pollution Act Overview.” http://www.epa.gov/oem/content/lawsregs/opaover.htm.
Environmental Protection Agency (EPA), ENERGY STAR Program. 2007 (August). *Report to Congress on Server and Data Center Energy Efficiency Public Law 109-431*, 7.
Environmental Protection Agency (EPA), Office of Transportation and Air Quality. 2010a (November). “EPA Finalizes 2011 Renewable Fuel Standards.” http://www.epa.gov/otaq/fuels/renewablefuels/420f10056.pdf.
Environmental Protection Agency (EPA), Office of Air and Radiation. 2010b (September). “EPA’s Transport Rule: What Does It Mean for Environmental Justice Communities?” Presentation. http://www.epa.gov/airtransport/pdfs/WebinarTransportRuleMaterials.pdf.
Environmental Protection Agency (EPA). 2011. “Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009.” Table ES-2. http://www.epa.gov/climatechange/emissions/downloads11/US-GHG-Inventory-2011-Executive-Summary.pdf.
“EU leaders agree on ambitious plan to battle global warming.” 2007 (March). *USA Today*. http://www.usatoday.com/news/world/2007-03-09-eu_N.htm.
Fischer, Carolyn, and Richard G. Newell. 2007 (February). “Environmental and Technology Policies for Climate Mitgation.” Discussion Paper 04-05, Resources for the Future. Washington, DC.
Frankel, Jeffrey. 1999 (June). “Greenhouse Gas Emissions.” Brookings Policy Brief Series 49. The Brookings Institution. http://www.brookings.edu/papers/1999/06energy_frankel.aspx.
Furman, Jason, Jason Bordoff, Manasi A. Deshpande, and Pascal Noel. 2007 (October). “An Economic Strategy to Address Climate Change and Promote Energy Security.” Strategy Paper. The Hamilton Project. http://www.brookings.edu/~/media/Files/rc/papers/2007/10climatechange_furman/10_climatechange_furman.pdf.
Gayer, Ted. 2011 (May). “A Better Approach to Environmental Regulation: Getting the Costs and Benefits Right.” Discussion Paper 2011-06, The Hamilton Project, Washington, DC.
Goulder, Lawrence H. 2004 (October). “Induced Technological Change and Climate Policy.” Pew Center on Global Climate Change, Washington, DC.
Graff Zivin, Joshua S., and Matthew J. Neidell. 2011 (April). “The Impact of Pollution on Worker Productivity.” Working Paper 17004. National Bureau of Economic Research. http://www.columbia.edu/~mn2191/w17004.pdf.
Greenstone, Michael. 2010 (July). “The Benefits of Cap-and-Trade Would Have Exceeded Its Costs.” The Hamilton Project, Up Front Blog. http://www.brookings.edu/opinions/2010/0730_climate_change_greenstone.aspx.
Greenstone, Michael, Elizabeth Kopits, and Ann Wolverton. 2011 (March). “Estimating the Social Cost of Carbon for Use in Federal Rulemakings: A Summary and Interpretation.” Working Paper 16913. National Bureau of Economic Research. http://www.nber.org/papers/w16913.pdf.
Hamilton, James. 2009a (April). “Causes and Consequences of the Oil Shock of 2007–2008.” U.C. San Diego Department of Economics. http://dss.ucsd.edu/~jhamilto/Hamilton_oil_shock_08.pdf.
Hamilton, James. 2009b (May). “Oil Prices and the Economic Downturn.” Testimony prepared for the Joint Economic Committee of the U.S. Congress.
Hamilton, James. 2011. “Historical Oil Shocks.” Working Paper. Table 1, 33. http://dss.ucsd.edu/~jhamilto/oil_history.pdf.
Hanna, Rema, and Paulina Oliva. 2011. “The Effect of Pollution on Labor Supply: Evidence from a Natural Experiment in Mexico City.”
Henderson, J. Vernon. 1996. “Effects of Air Quality Regulation.” *American Economic Review*. 86: 789–813.
Interagency Working Group on Social Cost of Carbon, United States Government. 2010 (February). “Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866.” http://www.epa.gov/oms/climate/regulations/scc-tsd.pdf.
Intergovernmental Panel on Climate Change (IPCC). 2007. “Summary for Policymakers.” *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press: Cambridge, United Kingdom and New York, NY.
Internal Revenue Service (IRS). 2011. “How to Depreciate Property.” Publication 946. Cat. No 13081F.
Internal Revenue Service (IRS). 2010. “2011 Standard Mileage Rates.” Notice 2010-88.
International Energy Agency (IEA). 2010 (September). “Energy Poverty: How to Make Modern Energy Access Universal?” *World Energy Outlook 2010*: 7. http://www.worldenergyoutlook.org/docs/weo2010/weo2010_poverty.pdf.
International Energy Agency (IEA) and the OECD Nuclear Energy Agency. 2010. *Projected Costs of Generating Power*. 2010 Edition. http://www.oecd-nea.org/pub/egc/.
Joskow, Paul. 2010 (September). “Comparing the Costs of Intermittent and Dispatchable Electricity Generating Technologies.” CEEPR Working Paper. http://econ-www.mit.edu/files/6317.
KNMI Climate Explorer. n.d. Accessed at http://climexp.knmi.nl/.
Lewis, James A., Sarah O. Ladislaw, and Denise E. Zheng. 2010 (June). *Earth Observation for Climate Change*. Center for Strategic and International Studies.

Mauzerall, D. L., and X. Wang. 2001. "Protecting Agricultural Crops from the Effects of Tropospheric Ozone Exposure: Reconciling Science and Standard Setting in the United States, Europe and Asia." *Annual Review of Energy and the Environment*. 26: 237–268.

Metcalf, Gilbert E. 2007 (October). "A Proposal for a U.S. Carbon Tax Swap: An Equitable Tax Reform to Address Global Climate Change." Discussion Paper 2007-12. The Hamilton Project, Washington, DC. http://www.brookings.edu/~/media/files/rc/papers/2007/10carbontax_metcalf/10_carbontax_metcalf.pdf.

Massachusetts Institute of Technology. 2003. *The Future of Nuclear Power.* http://web.mit.edu/nuclearpower/.

Muller, Nicholas, and Robert Mendelsohn. 2007. "Measuring The Aggregate Damages of Air Pollution in the United States." *Journal of Environmental Economics and Management* 54: 1–14.

National Academy of Sciences (NAS). 2010. *Hidden Costs of Energy.* National Academies Press. Washington, DC. 154.

National Research Council (NRC). 2001. *Energy Research at DOE: Was It Worth It?* National Academies Press: Washington, DC.

National Renewable Energy Laboratory, n.d. "Supporting Data for Energy Technology Costs." http://www.nrel.gov/analysis/tech_costs.html.

Nuclear Regulatory Commission (NRC), Office of Public Affairs. 2010 (August). "Fact Sheet on Nuclear Insurance and Disaster Relief Funds." http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/funds-fs.pdf.

Office of Management and Budget (OMB). 2010. "Historical Tables: Budget of the U.S. Government, Fiscal Year 2011." http://www.gpoaccess.gov/usbudget/fy11/pdf/hist.pdf.

Parry, Ian W. H., and Kenneth A. Small. 2005. "Does Britain or the United States Have the Right Gasoline Tax?" *American Economic Review*, 95(4): 1276–1289.

Parry, Ian W. H., Margaret Walls, and Winston Harrington. 2007 (January, rev.). "Automobile Externalities and Policies." Discussion Paper 06-26. Resources for the Future. http://www.rff.org/documents/RFF-DP-06-26-REV.pdf.

Reilly, J., S. Paltsev, B. Felzer, X. Wang, D. Kicklighter, J. Melillo, et al. 2007. "Global economic effects of changes in crops, pasture, and forests due to changing climate, carbon dioxide, and ozone." *Energy Policy*. 35(11): 5370–5383.

Rudolf, John Collins. 2010 (November). "End Ethanol Subsidies, Senators Say." The New York Times. http://green.blogs.nytimes.com/2010/11/30/end-ethanol-subsidies-senators-say/.

Scowcroft, Brent. 1996 (January). "Oral History: Brent Scowcroft." Interview. PBS *Frontline*. http://www.pbs.org/wgbh/pages/frontline/gulf/oral/scowcroft/1.html.

Sieminski, Adam. 2010 (April). "Energy and the Economy." Deutsche Bank. US EIA & JHU SAIS 2010 Energy Conference. http://www.eia.doe.gov/conference/2010/session5/sieminski.pdf.

Stavins, Robert N. 2001 (October, rev.). "Experience with Market-Based Environmental Policy Instruments." In *The Handbook of Environmental Economics*, ed. Karl-Goran Maler and Jeffrey Vincent, general ed. Kenneth Arrow and Michael Intriligator. http://www.hks.harvard.edu/fs/rstavins/Papers/Handbook_Chapter_on_MBI.pdf.

Stavins, Robert N. 2007 (October). "A U.S. Cap-and-Trade System to Address Global Climate Change." Discussion Paper 2007-13, The Hamilton Project, Washington, DC. http://www.brookings.edu/~/media/Files/rc/papers/2007/10climate_stavins/10_climate_stavins.pdf.

United Nations Development Programme (UNDP) and World Health Organization (WHO). 2009 (November). "The Energy Access Situation in Developing Countries." 1. http://content.undp.org/go/cms-service/stream/asset/?asset_id=2205620.

Update of the MIT 2003 Future of Nuclear Power. 2009. MIT Energy Initiative. http://web.mit.edu/nuclearpower/pdf/nuclearpower-update2009.pdf.

Weyant, J. P., and J. N. Hill, 1999. "Introduction and Overview." In "The Costs of the Kyoto Protocol: A Multi-Model Evaluation." J.P. Weyant, ed. *Energy Journal*. Special Issue: vii–xliv.

World Health Organization (WHO). 2009. "Global Health Risks: Mortality and Burden of disease attributable to selected major risks." 11–12. http://www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf

World Nuclear Association. 2011 (March). "Economics of Nuclear Power." http://www.world-nuclear.org/info/inf02.html.

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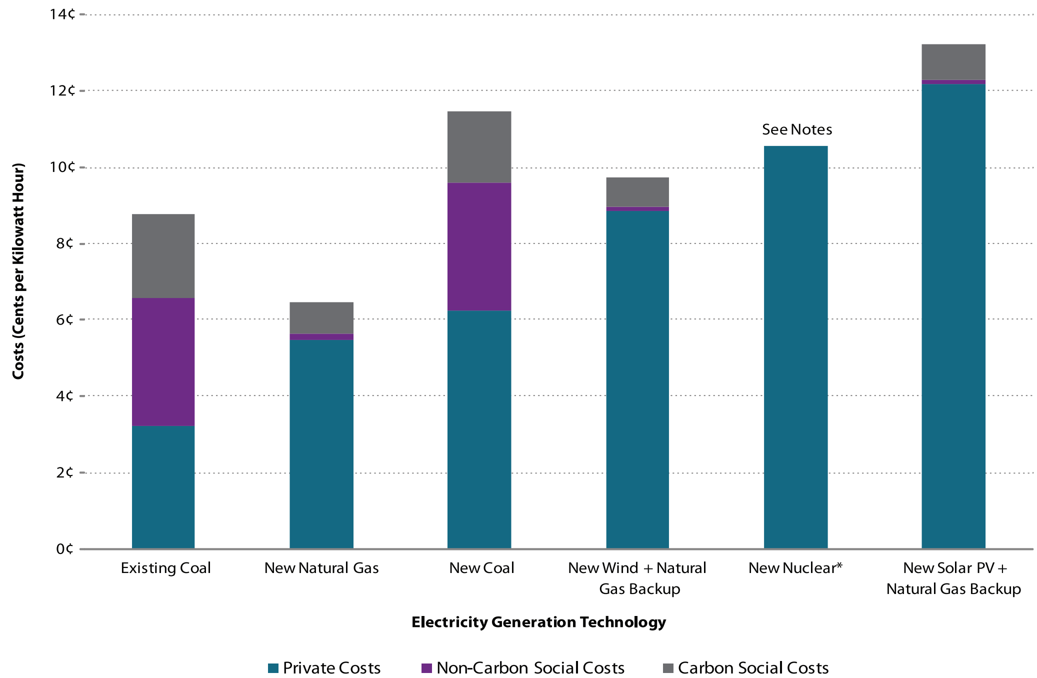
The Private and Social Costs of Electricity Generation



Source: See text.

Note: Non-carbon social costs include only damages associated with operating the plant, not upstream costs from mining, drilling, or construction. *The non-carbon social costs of nuclear power, including the risk of serious accidents, have not been quantified for this figure.

The figure above illustrates the private and social costs of producing electricity from different energy sources. Costs of building, maintaining, and fueling plants make up the private costs. The non-carbon social costs are almost entirely damages to health—increased respiratory disease, infant mortality, and reduced life expectancy associated with air pollution. The monetized value of these damages comes from a 2010 National Academy of Sciences report. The climate-change related damages are based on the United State Government's recent adoption of $21 as the social cost of carbon.

When private costs alone are considered, coal power plants appear to be a great deal as they can deliver a kilowatt hour of electricity for just 3.2 cents. Based on this cost advantage, these plants account for roughly 45 percent of the electricity in the United States.

While this appears to be a bargain, the reality is that the true costs of coal are much higher—a full 170 percent higher. The reason is that each kilowatt hour of coal-generated electricity comes with an additional 5.6 cents of damages to our well-being: 3.4 cents of non-carbon social costs and 2.2 cents of climate-change related damages. Although these costs are not listed on our monthly utility bills, they are nevertheless real—they show up as shorter lives, higher healthcare bills, and a changing climate that poses risks to our way of life.

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