THE HAMILTON PROJECT

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An Economic Strategy to Address Climate Change and Promote Energy Security

Jason Furman, Jason E. Bordoff, Manasi Deshpande, and Pascal J. Noel

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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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Abstract

The related issues of climate change and energy security are now generally accepted as major challenges. U.S. greenhouse gas emissions contribute to climate change while its reliance on oil reduces its economic and national security. To tackle both problems, the United States must substantially reduce its consumption of fossil fuels.

This paper presents a three-part strategy for addressing climate change and promoting energy security. First, the government should price carbon and oil correctly so that the private sector has an incentive to reduce their use. Second, the government should increase and refocus public investments on basic research and on long-run speculative energy technologies. Finally, the United States should lead by example and engage major emitting nations in an international response to climate change.

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Introduction

It is now almost universally accepted that global climate change is a reality. In the past century, the Earth's average annual surface temperature rose 0.7 degrees Celsius. There is little doubt that humans have contributed to this warming, particularly by burning fossil fuels such as coal and oil. The Intergovernmental Panel on Climate Change (IPCC 2007) asserts with "*very high confidence* [emphasis in original] that the globally averaged net effect of human activities since 1750 has been one of warming" (5). In fact, this year's Nobel Peace Prize was awarded to Al Gore and the IPCC for their efforts on the issue of climate change. The IPCC projects that, if emissions continue on their present course, global temperatures will rise another 4 degrees Celsius by 2100. This temperature change may trigger massive climatic shifts, including rising sea levels, more frequent and more severe storms, increased flooding and drought, and other dramatic changes in weather patterns. Economists estimate that the eventual damage is likely to be substantial. Estimates indicate that a doubling of greenhouse gas (GHG) concentrations would reduce GDP by 1.0 to 1.5 percent in developed countries, and by 2.0 to 9.0 percent in developing countries, whose economies depend heavily on agriculture (Cazorla and Toman 2000). Even these estimates, however, do not reflect the heavy human impact from increased incidence of water- and insect-borne diseases as well as the loss of lives, homes, and livelihoods from flooding or drought. Beyond these somewhat predictable developments lies the potential for low-probability but massively catastrophic outcomes (Weitzman 2007).

While climate change is a recently recognized problem, energy security has been a concern for the United States since the oil price shocks of the 1970s. Part of the energy security problem is economic: oil shocks have played a major role in nine of the ten U.S. recessions since World War II. Sharp increases in oil prices can disrupt firms' usual methods of production and reduce households' purchasing power, often triggering drops in consumer confidence and concomitant reductions in economic activity (Hamilton 1983, Hamilton and Herrera 2004). The higher oil prices can also feed into higher prices of other goods and thereby induce contractionary monetary policy (Bernanke et al. 1997). Lower energy intensity, improved management of monetary policy, and greater flexibility of the economy have decreased, but not eliminated, the economy's vulnerability to oil shocks (CBO 2006a).

Another part of the energy security problem is geopolitical. Thomas L. Friedman, Pulitzer Prize–winning journalist and columnist for the *New York Times*, presents evidence that oil-wealthy states increasingly resist international norms and conventions as their oil wealth rises (Friedman 2006). U.S. foreign policy is limited by the threat that these oil-supported authoritarian governments could withhold oil from world markets and trigger shortages and price spikes. Friedman also shows that higher oil prices cause worrisome domestic impacts in these "petrolist" countries, eroding "free speech, free press, free and fair elections, an independent judiciary, the rule of law, and independent political parties." Furthermore, oil dependence has contributed to a U.S. military presence and political involvement in the Middle East over the past 50 years, diverting U.S. resources and creating popular resentment against the United States that terrorist organizations have exploited as a recruiting tool while using oil wealth to fund their operations.

The question now is not *whether* to do something about these related challenges, but rather *what* to do about them. Even here, economists across the political spectrum generally agree on how to deal with the problems of climate change and energy security, perhaps more so than on most other economic issues. The central goal of climate policy is reducing the buildup of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere, either by reducing the use of fossil fuels or by finding ways to prevent emissions from entering the atmosphere. The specific and related goal of energy security is reducing oil consumption, the most effective way to decrease U.S. vulnerability to oil price shocks, mitigate the geopolitical costs associated with our vulnerability, and reduce transfers to oil-exporting countries.

A large body of economic research shows that the United States can make substantial reductions in emissions and petroleum consumption at a relatively small cost, and that these policies can have ancillary benefits such as reduced traffic congestion and local pollution, and fewer car accidents. The same body of research, however, delivers a clear warning: if we adopt the wrong policies on either issue, the costs could be much larger—for the economy as a whole or for large segments of the population, or both.

This paper draws on economic research, including released and forthcoming papers from The Hamilton Project, to synthesize the economic consensus on climate change and energy security into a specific three-part strategy. It provides a framework for thinking about the right policies, rather than proposing a specific set of parameters. This paper focuses on the implications of basic economic principles on policies for energy and climate change, recognizing that the answers to some of the most important questions—such as how to convince the major developing nations to join climate change mitigation efforts—may lie outside the realm of economics.

The Relationships Among Climate Change, Energy Security, and Energy Prices

Many policy discussions address the issue as if the goals of addressing climate change and promoting energy security were identical, or at least highly complementary. In a few important respects they are. Petroleum is responsible for 44 percent of the CO_2 emissions from U.S. primary energy consumption (EIA 2007a). As a result, reducing America's oil use would both help mitigate global climate change and improve America's energy security. Conversely, most efficient policies to reduce carbon use would have the effect of curbing American oil consumption—though not by a large enough amount to fully address the energy security challenge.

But in some important and underappreciated respects, the goals of minimizing climate change and enhancing energy security can be quite different and even at odds with one another. First, the problems differ in timing. Successful climate change policies can phase in emissions reductions over time because the full challenges of climate change will unfold over decades or even centuries. In contrast, the risks associated with energy security already threaten the U.S. economy and limit its foreign policy, thereby requiring more immediate reductions in oil use.

Second, the geographical scope of these problems differs. Promoting energy security in the United States is in large part a matter of unilateral domestic policy to provide incentives for decreasing oil consumption. But climate change is an inherently global phenomenon, in that emissions from any part of the world make an equal contribution to the problem. Any successful climate policy is thus impossible without international cooperation, primarily from major GHG-emitting nations like China and India.

Third, compared to coal, oil has relatively little carbon per unit of energy. As a result, putting a price on carbon emissions—which is the central element of an efficient climate change strategy—would result in a much larger increase in the price of coal than in the price of gasoline. Carbon policies may thus do relatively little to curb oil use, and certainly would not induce large enough oil demand reductions on their own to seriously improve energy security.

Finally, some policies that could enhance energy security may actually exacerbate climate change. A prime example is coal-to-liquid technology, in which coal is transformed into a diesel fuel that can be used in place of conventional oil. Although this technology would promote energy security by reducing oil consumption, it would emit more than twice the amount of GHGs as conventional oil production emits, and would require intense coal mining and massive amounts of water (EPA 2007a; DOE 2006a).

It is important to note that, while the goals of mitigating climate change and promoting energy security are popular with the public, they are also at odds with another popular goal: lowering gasoline prices and other energy prices. The 79 percent increase (adjusted for inflation; EIA 2007b) in the price of gasoline over the past eight years is understandably troubling to families facing higher energy costs, but any long-run solution to climate change or energy security will require higher, not lower, prices for fossil-fuel based energy, including gasoline, electricity, and home heating oil.

The implications of these higher prices, however, would be very different from the higher prices we experience today. For example, if OPEC constricts supply to raise prices, then money is transferred from American consumers to the governments of oil-exporting nations. In contrast, if a domestic tax or cap-and-trade system were to raise prices, this would generate revenue for the United States. Returning this revenue to families in the form of progressive tax cuts or benefit increases would minimize the effect of higher prices on American families. Moreover, at least in the case of petroleum, these policies could capture some of the surplus profits that currently go to oil-exporting nations and transfer them to American consumers. The implementation of the tax rebates or other compensation is critical because the direct impact of carbon pricing and the resulting higher energy prices would be regressive. Low-income households spend 14 percent of their income on energy, compared to the national average of 3.5 percent (DOE 2006b).

One lesson of this discussion, then, is that much or all of the revenue from pricing oil and carbon emissions should be used to address the effect of higher energy prices on consumers. This can be done either by rebating the money directly or by using it to reduce the deficit, which would minimize the need for future tax increases or for reductions in benefits like Medicare or Social Security. If the revenue is used, instead, for inefficient spending or regressive tax cuts, the effect on American consumers would be similar to the burden felt by American consumers when OPEC raises prices.

Another lesson is that it is possible to develop policies that help with both climate change and energy security, but that the development of coordinated policies is not automatic. In designing policies, policymakers need to balance both goals and ensure that progress toward one goal is not counterproductive to progress toward the other. This paper emphasizes that policymakers should not assume that policies will automatically address both problems.

A Summary of the Three-Part Strategy

This paper proposes a three-part strategy to address climate change and promote energy security.

Part 1. Price carbon and oil correctly so that the private sector has an incentive to reduce their use. Carbon and other GHG emissions, as well as oil use, can be reduced in myriad ways: by adopting more energy-efficient technologies, shifting to renewable energy or lower-carbon energy, capturing and storing carbon, or making behavioral changes like driving less. The government has limited knowledge of the most efficient ways to reduce emissions, especially since the cost of reductions varies enormously between the different methods and among firms and across families. Instead of mandating specific individual and firm level actions, the government should pursue this more effective and less costly policy:

- The government should put a price on carbon emissions, either by auctioning off a limited number of tradable permits to emit carbon (a *cap-and-trade system*) or by implementing a tax on carbon emissions (a *carbon tax*).
- The government should also consider additional market measures to make the price of oil commensurate with its economic and national security costs, although pricing carbon would already increase the price of oil closer to its true social cost.
- Revenue generated by either a tax or a cap-and-trade system should be used to address the distributional problems associated with the higher energy prices they will generate.
- Once a price mechanism is put in place, the govern-

ment should re-evaluate many current regulatory or command-and-control policies that become at best superfluous, and at worst, costly and inefficient.

Once firms and individuals are faced with the social cost of their actions, they will naturally find the best way to reduce their own emissions and oil consumption given the cost they face. Both methods of pricing carbon—cap-and-trade and a carbon tax—are economically similar. As a result, the critical questions for policymakers are, "Which is more politically feasible?" and, "Which is more likely to be implemented in a sound manner?"

Part 2. Increase and redirect public investments on basic research and on long-run speculative energy technologies. Technological breakthroughs are essential for breaking America's oil addiction and reducing the cost of meeting GHG-emissions goals. Pricing carbon will stimulate a large increase in private-sector research. But the public sector also has an important role to play. Several components of this role include:

- The federal government should reorganize efforts by creating an energy technology initiative for basic research into ideas with the potential for eventual commercial application. The goal is to sponsor basic research that the private sector is unlikely to undertake on its own while taking into account market demand and commercial viability.

- Federal efforts should also invest in highly speculative, high-risk, high-reward areas—the sort of blue-sky, long-term research for which no commercial application may be apparent.

- Federal efforts should be scaled up, but in a manner that is mindful of diminishing returns.

- The government should fund this increase by redirecting expenditures on counterproductive or superfluous energy subsidies. These reforms could generate up to $14 billion annually in new funding.

- Public policy should use prizes, tax reform, and patent reform to encourage private innovation.

Part 3. Lead by example and engage major emitting nations in an international response to climate change. Although international engagement would help in addressing energy security, the most important steps are domestic. In contrast, international engagement is indispensable in the case of climate change because the causes, and potential consequences of climate change are all truly global. Despite the many complexities involved in such an approach, the United States can follow several guiding principles to facilitate international cooperation:

- The United States should set an example through the unilateral adoption of measures to curb GHGs. Leading by example would encourage the major developing countries to act.

- The United States should focus on building a broad-based coalition of major emitting nations to tackle climate change over time, rather than encouraging steep near-term emissions reductions from a few countries.

- The United States should take active steps to assist developing countries in reducing their emissions.

Part 1. Price Carbon and Oil Correctly So That the Private Sector Has an Incentive to Reduce Their Use

The problem of climate change stems from emissions of carbon and other greenhouse gases. Similarly, energy security is threatened by excessive consumption of oil in the United States. Making firms and consumers face the social costs of carbon emissions and oil use is the single most important tool for mitigating climate change and promoting energy security. As a result, a price mechanism for carbon emissions or gasoline, or both, is supported by economists and policymakers across the political spectrum, from Gary Becker, Alan Greenspan, and N. Gregory Mankiw to Al Gore, Paul Krugman, and Joseph Stiglitz.

This section discusses two "price mechanisms," or ways to attach a price to carbon emissions or oil such that their climate and energy security costs are reflected in this price. The first mechanism is a carbon tax, in which the government would establish a direct price on carbon emissions and allow the market to determine the resulting quantity of emissions. The second mechanism is a cap-and-trade system, in which the government would establish a target quantity of emissions and issue tradable permits to firms in the amount of this target, allowing the market to determine the price of these permits. This section discusses why price mechanisms are better than command-and-control policies and how the two price mechanisms differ. Since well-designed versions of the two price mechanisms have similar effects, the most important considerations in deciding between them may be their probability of being designed properly and their political feasibility.

The goal of reducing emissions. Climate change is caused by the buildup of CO_2 and other greenhouse gases in the atmosphere. The atmospheric concentration of CO_2 has risen from about 280 parts per million (ppm) in the pre-industrial era to 379 ppm in 2005 (IPCC 2007). Like a greenhouse, this atmospheric layer allows heat from the sun in but traps the heat as it reflects off the Earth. As atmospheric concentrations increase, the Earth's surface warms, triggering a range of climatic shifts, including rising sea levels and increased frequency and severity of storms. Atmospheric concentrations of CO_2 are projected to rise to anywhere from 600 ppm to 1,550 ppm by 2100, depending on the action taken to reduce emissions (IPCC 2007). Such an increase would induce climate changes far more severe than those the world has experienced to date. Scientists generally agree that atmospheric concentrations of CO_2 should be stabilized at 450 to 550 ppm to avoid serious climate consequences.

The atmospheric impact of a ton of carbon is identical whether it is emitted by a driver or a power plant, whether it is emitted in the United States or China, and even—for the most part—whether it is emitted now or 20 years from now.

TABLE 1

Source of Carbon Emissions from Fuel Consumption, 2005

	Coal	Oil	Natural Gas	Total
Residential	12%	2%	6%	**21%**
Commercial	12%	2%	5%	**18%**
Transportation	0%	32%	1%	**33%**
Industrial	12%	8%	8%	**28%**
Total	**36%**	**44%**	**20%**	**100%**

Source: Calculations based on Stavins (2007), includes indirect emissions from electricity use.

Climate change is a true global commons problem in that carbon emitted in one country contributes just as much to climate change as carbon emitted in another. The atmospheric impact of a ton of carbon is identical whether it is emitted by a driver or a power plant, whether it is emitted in the United States or China, and even—for the most part—whether it is emitted now or 20 years from now.[1] Table 1 shows U.S. CO_2 emissions from fuel consumption by source and sector in 2005.

The goal of reducing oil consumption. Energy security entails a similar challenge, although in this case the goal is to reduce the consumption of oil in the United States. Spending less on oil as a share of total output would reduce the macroeconomic costs from oil price volatility (Hamilton 2005). With oil playing a smaller role in the economy, a sudden or gradual price increase would have a smaller effect on economic activity and the overall price level. Given that the United States accounts for one-quarter of world oil demand, reducing U.S. oil consumption would decrease revenues for authoritarian oil-exporting regimes, curbing their international influence and repressive domestic tendencies (Friedman 2006; EIA 2007c). Reducing revenues for many of the largest oil exporters could also reduce funds flowing to terrorist organizations, though to be sure only a tiny fraction of oil revenues have been siphoned to finance terrorism. Finally, significantly reduced oil consumption could alleviate the need for some of the U.S. military presence overseas, decreasing resentment among the public in these countries and preserving valuable American resources (Delucchi and Murphy 2006.)

There is debate about whether the goal should be (a) reducing oil *consumption* by reducing domestic demand, or (b) reducing oil *imports* by either reducing domestic demand or increasing domestic supply. It is true that reducing oil imports through raising domestic supply has benefits, including the potential to lower world prices and to reduce transfers to oil-exporting nations. However, reducing U.S. demand for oil has two major benefits over raising domestic supply. First, lowering energy demand would have significant climate benefits, while increasing the domestic oil supply would exacerbate the climate problem by lowering prices and encouraging consumption.

Second, a reduction in the demand for oil would enhance energy security more than a comparable increase in supply. Because oil can be shipped at low cost relative to its value, the price of oil is essentially determined by the world market regardless of where it is produced. While reducing imports may decrease payments to oil-exporting nations, it will not decrease U.S. vulnerability to oil price shocks since turbulence in any oil-producing nation—even those from which the United States does not import oil—affects the global price of oil, whether it comes from the United States or Saudi Arabia or Mexico. As long as oil continues to play a dominant role in the U.S. economy, oil price shocks will raise risks of both recession and inflation, even if the United States reduces imports substantially. Since reducing imports cannot shield the U.S. economy from shocks, such a policy would not free U.S. foreign policy, reduce its strategic interest in stabilizing Middle East oil supplies, or prevent money from being spent securing that interest militarily. Indeed, it is telling that Iran continues to play its oil card in international negotiations even though the United States has not imported a drop of Iranian oil in 25 years (Sandalow 2007). Promoting energy security will therefore re-

1. Climate is affected by the total amount of CO_2 and other GHGs in the atmosphere, called the concentration of GHGs, at any point in time. CO_2 has an atmospheric lifetime of 50 to 200 years (EPA 2006). As a result, a ton of carbon emitted in 2007 or 2027 will add essentially the same amount to atmospheric concentrations and thus have a similar effect on temperatures.

quire a comprehensive plan to reduce domestic oil consumption.

Choosing the right policy mechanism. Given these goals, policymakers have a fundamental choice between two approaches to achieve reduced oil consumption and GHG emissions. In the first system, known as command-and-control, the government either sets source-specific emission and consumption limits or requires the adoption of particular technologies. The alternative to command-and-control is a market-based price mechanism, either a carbon tax or cap-and-trade system, in which the government puts in place incentives to reduce carbon emissions but leaves specific decisions to individual firms and consumers. It is also possible to combine market mechanisms with command-and-control policies. The next section details the advantages of a market-based approach, primarily as it relates to the goal of mitigating climate change. The arguments in favor of market mechanisms are identical in the case of reducing oil consumption.

The Limitations of a Command-and-Control System

Command-and-control systems to reduce emissions or curb oil consumption come in a variety of forms. The canonical form is a specific mandate, like the prohibition of chlorofluorocarbons or a minimum requirement for energy efficiency for appliances. Other examples from recent energy and environmental policy include Corporate Average Fuel Economy standards (CAFE), which require new cars to achieve a certain average fuel economy; renewable portfolio standards, which specify the percentage of electricity generation that must come from renewables; and gasoline blend requirements, which mandate the percentage of fuel that must come from renewable sources like ethanol.

Another form of command-and-control is the government trying to pick "winners and losers"—specific technologies it believes will be effective or ineffective. For example, it can pick winners by offering subsidies for specific technologies like hybrid cars and corn-based ethanol, or by funding specific demonstration projects like it did with the Synthetic Fuels Corporation in the 1980s.

Command-and-control policies have achieved some successes. For example, CAFE standards have reduced gasoline consumption, improving U.S. energy security and helping to reduce carbon emissions. The key question going forward, however, is not whether these programs are effective, but rather whether they are the most effective way to achieve certain goals, and in particular whether there are more economically efficient approaches that are also politically feasible. This question is especially important as the United States becomes substantially more ambitious about the magnitude of its emissions reductions and other goals. The answer is simple: command-and-control policies have several important drawbacks that would be minimized if a market mechanism were used instead.

First, the government has limited knowledge of the best ways to reduce GHG emissions or oil consumption. Choosing the best way among myriad options would require a sophisticated understanding not only of technology and economics, but also of individual preferences. The government would have to know, for example, which factories could reduce their energy use at the lowest cost and which people would be most willing to switch to public transportation.

The government's information limitations are compounded by two factors. The first is that some efficiency standards are likely to be the result of political pressure from special interests rather than objective cost-benefit analysis. The less knowledge the government has, the more powerful these political factors will be. Moreover, the economy evolves rapidly while regulations tend to persist and to be slow to change.

Second, command-and-control systems generally cover only a fraction of the economic and behavioral choices that affect emissions or oil consumption. For example, renewable portfolio standards affect only one dimension of choice in the production of one source of emissions—electricity generation—and therefore does not necessarily take advantage of the cheapest way to reduce emissions, even within the electricity sector. Similarly, CAFE only affects car purchases but does not address choices like how much to drive or whether to carpool. Other command-and-control policies, such as efficiency standards for appliances and homes, leave untouched a large fraction of the decisions that could result in GHG emissions.

This limited scope of command-and-control systems can result in unintended side effects that undo some of the benefits of the regulation or raise the cost of the regulation. In particular, leaving some types of activities uncovered will encourage those activities relative to the regulated activities. CAFE standards, for example, require the purchase of more efficient automobiles, but because those automobiles are cheaper to operate per mile, these standards may actually encourage more driving (Parry et al. 2007; Fisher et al. forthcoming). Moreover, since most efficiency standards apply only to new purchases, and since they raise the price of these new purchases, they create an incentive for people to use their old, inefficient cars and appliances for longer. Imperfectly set standards can also create counterproductive incentives for consumer choice; for example, they can push consumers from automobiles, which are covered by CAFE standards, to SUVs, which are covered by looser standards and have poor fuel economy.

Finally and least appreciated, command-and-control systems can have adverse distributional consequences that are both hidden and difficult to remedy. A standard that mandates a minimum level of energy efficiency for appliances, for example, will tend to raise the price of appliances. Facing higher costs from the standards, manufacturers are likely to pass these costs down to consumers in the form of higher prices. These price increases will have a bigger percentage impact on the purchasing power of a low-income family than it does on a high-income family. But in contrast to, say, a carbon or oil tax, these impacts are hidden and have barely been studied by researchers. Moreover, even if the impacts were understood, it would be difficult to remedy them because standards do not raise a pool of federal money that can be used to help alleviate the disproportionate impact of higher energy prices on families.

Incentives for particular technologies like hybrid cars or corn-based ethanol are similar to command-and-control regulations. In an economy without a price on carbon or oil, these incentives can be a very effective way to improve efficiency, reduce emissions, and promote energy security. For example, subsidizing cars that use less gasoline can accomplish many of the same goals as taxing cars that use more gasoline. But these policies also suffer from the same information limitations as command-and-control policies. Moreover, they amount to about $14 billion annually—costing each household more than $110, the equivalent of a 10 percent increase in the household's electricity bill.

Finally, the government can attempt to pick the next set of technological winners and make investments in them. To date, this process has been remarkably unsuccessful. Peter Ogden, John Podesta and John Deutch (2007) note the lack of success of many DOE demonstration projects since the 1970s, citing as examples the Clinch River Breeder Reactor from the early 1970s, largescale synthetic fuel projects, and the Central Solar Power Tower in California.

Many command-and-control policies aimed at reducing GHG emissions and increasing energy security have accomplished some of their goals, but often with costly side effects and economic inefficiencies. These side effects would only grow larger if the policies were scaled up to accomplish the magnitude of emissions reductions contemplated under most current climate change policies. Fortunately, almost all of these problems can be remedied by an alternative set of policies that rely on market mechanisms.

A Better Approach: Using Price Mechanisms

A more cost-effective way to reduce carbon emissions and oil consumption is to use the power of the market. Voluntary exchange in competitive markets generally makes everyone better off—the purchaser will only buy a product if he or she values it at more than the sales price, the seller will only sell it if it costs less than the sales price to produce, and everyone not a party to the transaction is indifferent. This presumption breaks down when the product in question produces harms that are not captured by the buyer or the seller—what economists call an *externality*. As discussed in the previous section, the best solution is not a command-and-control approach in which the government decides exactly how this socially costly action should be reduced. A better solution is a market mechanism which would attach a price to the socially costly behavior and then let producers and consumers make their own decisions on the best way to reduce that behavior given its cost.

In the context of carbon emissions and oil, there are two ways to generate this price signal: a carbon tax and a cap-and-trade system. We consider the case of carbon emissions here, though the description is analogous for oil consumption. The classic solution is a Pigouvian tax, named after the economist who first proposed it, in which the producer or consumer would pay a tax equal to the social damage of emitting carbon. Alternatively, the same outcome could be achieved using a cap-and-trade system. Unlike a tax, which would set a price target for carbon and allow the market to determine the resulting quantity of carbon emissions, a cap-and-trade system would set a quantity target and allow the market to determine the price of carbon. In this case, the government would issue a limited number of permits for the right to emit carbon, and then allow producers and consumers to trade those permits among themselves. The price of these permits would be determined by the market based on their scarcity. Firms that wanted to emit carbon would have to purchase permits at this price, in much the same manner that they would have to pay the government a tax to emit carbon under a carbon tax system.

A key question in designing a cap-and-trade system is how the permits are allocated. The limited number of permits issued by the government are a scarce resource that could have a total market value of $100 billion or more annually. At one extreme, these permits could be given away for free to industries that emit substantial quantities of carbon and other GHGs, a process sometimes called "grandfathering." This allocation method was used in the Acid Rain Program, a cap-and-trade system in the United States to reduce sulfur dioxide emissions, and in the European Union Emissions Trading Scheme, a cap-and-trade system in Europe to reduce carbon emissions. At the other extreme, the permits could be auctioned to the highest bidders and the revenue generated used for tax cuts, public investments or deficit reduction. Alternatively, policymakers could undertake a mixture of free allocation and auctioning. Most economists think the bulk of the cost of permits is passed through to consumers. Therefore, they generally are opposed to allocating more than 15 percent of permits for free because they consider such free allocations a transfer payment worth tens of billions of dollars or more to the favored industries. Most economists argue instead that 85 to 100 percent of permits should be auctioned off with the proceeds used to help protect families from the higher cost of energy or to pay for tax cuts, public investments, or deficit reduction that will strengthen the overall economy.

The major advantages of price mechanisms over command-and-control regulations are innovation, flexibility, and cost effectiveness. Under either a carbon tax or cap-and-trade system, firms would search for methods to reduce emissions in order to avoid paying the tax or using permits. There are numerous ways a firm could reduce emissions, from changing its production process to shifting the sources of its energy or raw materials. Firms that figured out the most cost-effective ways to accomplish this would succeed, and, in a competitive economy, other firms would either have to copy their best practices or cease to exist. Given the proper incentives, the decentralized decisions of profit-maximizing firms would lead to substantial innovation and ingenuity in curbing carbon or oil use—well beyond anything that regulators could envision.

Firms would pass on most of their increased costs to consumers, who would respond to these higher prices by adjusting their behavior.[2] For example, if gasoline prices were to rise, consumers would respond by buying more fuel-efficient cars, switching to public transportation, carpooling, or driving less. The mixture of these solutions would vary from person to person, based on each individual's tastes and personal circumstances. As with firms, the flexibility of price mechanisms would allow consumers to make the most cost-effective choices in response to these price signals.

Comprehensive market mechanisms are well suited to the nature of the climate and energy security challenges. As noted earlier, the reduction of either a ton of carbon from automobiles or a ton of carbon from electricity generation would have the same effect on mitigating

2. Economic theory predicts that this price pass through would happen regardless of how permits were allocated. For example, if a firm that emits carbon was given free permits it would still pass on the increase in the *marginal cost* of carbon emissions reductions to consumers, pocketing the value of the permits as a windfall profit.

climate change. Similarly, it does not matter which cars use less oil, as long as total consumption falls. The key to addressing climate change and energy security is to generate emissions and consumption reductions wherever they are cheapest; a market-based option that prices carbon emissions provides precisely the incentive to undertake the most cost-effective carbon reductions.

Impact and Cost of Price Mechanisms

Both types of market mechanisms have been proposed for tackling the climate and energy problems. For example, in discussion papers for the Hamilton Project, Gilbert Metcalf (2007) and Robert Stavins (2007) develop proposals for a carbon tax and cap-and-trade system, respectively.

A carbon tax would result in a price on the carbon content of oil. Additional measures should be considered to reflect energy security costs and other costs associated with oil. For example, Greg Mankiw, Harvard economist and former chair of President Bush's Council of Economic Advisors, has proposed phasing in a $1 per gallon gasoline tax over a decade.[3] Martin Feldstein of Harvard recently proposed a system of tradable gasoline rights as a way of reducing oil consumption to increase economic and national security.[4] Others have proposed further measures to price gasoline in a way that reflects separate externalities correlated with its use, most notably congestion and accident costs.

A price mechanism could generate substantial cuts in emissions with minimal effects on GDP. A cap-and-trade system with a target reduction of 75 percent in 2050 would reduce GDP by just 0.5 percent.

TABLE 2

Consumer Price Impacts of a Carbon Tax

Commodity	Price Increase (%)
Electricity and Natural Gas	14.1
Home Heating	10.9
Gasoline	8.8
Air Travel	2.2
Other Commodities	0.3 to 1.0

Source: Metcalf (2007). A 2003 tax of $15 per metric ton of CO_2 (year 2005 dollars) is assumed to be passed fully forward to consumers.

For example, a forthcoming paper by The Hamilton Project will examine congestion pricing to reduce local traffic, a policy that would also have beneficial side effects for climate change and energy security.

The following analysis evaluates the macroeconomic costs and price impacts of market mechanisms for controlling GHG emissions, but the same logic would apply to a system that was intended to discourage oil use and increase energy security. The imperative for designing such mechanisms in a distributionally equitable way, explained in the next section, would also apply to an oil-pricing mechanism.

Macroeconomic costs. Various analyses indicate that market mechanisms can achieve desired emissions reductions at acceptable aggregate costs. Stavins (2007) models two scenarios in which emissions in 2050 are cut by either 38 percent or by 75 percent relative to the baseline. He finds that they would cost 0.2 percent of GDP and 0.5 percent of GDP, respectively, in 2050.[5] Similarly, a recent report by the Congressional Budget Office estimates that a cap-and-trade system with a 15 percent target reduction in carbon emissions in 2010 would cut GDP by 0.28 percent if allowances were given away for free and just 0.13 percent if they were auctioned with proceeds used to reduce distortionary taxes (CBO 2007). These small costs must be compared to the

3. Greg Mankiw, "The Pigou Club Manifesto," *Wall Street Journal*, October 20, 2006.
4. Martin Feldstein, "Tradeable Gasoline Rights," *Wall Street Journal*, June 5, 2006.
5. Note that the welfare loss is 0.2 percent and 1.4 percent, respectively, which reflects the substitution of products and labor-leisure, as well as the reduction in output.

gains from mitigating global climate change, including gains that come about when major developing countries reduce their own emissions in response to action by the United States.

Note that both a carbon tax and a cap-and-trade system would be more economically efficient if they were integrated into a global system. By expanding opportunities for low-cost emissions reductions, such integration could minimize macroeconomic costs in the United States of reducing emissions. In the absence of integration, there is a risk of "carbon leakage," whereby carbon-intensive industries could relocate to countries that do not have climate policies in place. These issues are discussed in Part 3.

Consumer price impacts. A price mechanism would also have an effect on consumer prices. Metcalf (2007) estimates the impact on prices of consumer goods from a tax of $15 per ton of CO_2. He finds that the price increases would be greatest for electricity, natural gas, and gasoline.[6] Economic theory and evidence predict that if the price of a good rises, people will use less of it. After the oil price shocks in the 1970s, for example, consumers and companies took a number of steps to encourage efficiency, and gasoline consumption actually fell from 1973 to 1985 (EIA 2007c) despite a 50 percent inflation-adjusted increase in total consumer expenditures (BEA 2007). Conversely, when oil prices were relatively low from the mid-1980s through the late 1990s, cars got heavier and less fuel-efficient (EPA 2007b).

Indeed, Metcalf predicts that his carbon tax would discourage the consumption of carbon-intensive products, which would in turn cause a 14 percent reduction in greenhouse gas emissions. Over time, a higher carbon tax rate would lead to increased technological change and a greater reduction in emissions. The results would be similar for an analogous cap-and-trade system.

Equivalence under certainty. In the hypothetical case of complete certainty, a carbon tax and cap-and-trade system would result in nearly identical aggregate costs, consumer price impacts, and reductions in carbon emissions.[7] For example, suppose the government were to issue tradable permits for carbon emissions that settled at a market value of $15 for a permit to emit a ton of CO_2. In this case, just as with a $15 per ton CO_2 tax, any firm that could reduce CO_2 emissions for less than $15 per ton would do so, while any firm that would have to pay more than that would purchase a permit instead.

This economic equivalence under complete certainty of a carbon tax and a cap-and-trade system is most clearly illustrated in the respective proposals by Metcalf (2007) and Stavins (2007). Both propose applying the price mechanism "upstream"—at the producer rather than the consumer level. Coal-mining firms would pay a tax or use permits for the coal they extracted at the mine, while natural gas firms would pay at the wellhead or upon import. For the natural gas producer, the market price of the permits at, say, $15 per ton of CO_2, would be exactly equivalent to paying a $15 tax per ton of CO_2. It makes no difference to the natural gas producer whether it pays $15 to the government in taxes or $15 to a private trader for a permit.[8] As a result, both price mechanisms would have identical impacts on the behavior of fossil fuel producers and the price of fossil fuel, and thus on the decisions of those who use fossil fuels.

Low-income households spend 14 percent of their income on energy, compared to the national average of 3.5 percent. To be consistent with broad-based growth, a policy that raises energy prices would need to compensate families.

6. A carbon tax can be levied in units of carbon or CO_2. One can convert a tax rate denominated in units of CO_2 to a rate in units of carbon by multiplying by 44/12. Thus a $15 per ton CO_2 tax is equivalent to a tax rate of $55 per ton of carbon.
7. There are some potentially important economic differences, including the different incentives the two systems would create for regulated utilities.
8. The economic equivalence holds even if the natural gas producer is given the permits for free by the government, although the distributional impact would be different. In this case, for each ton of CO_2 that is extracted, the natural gas producer loses one permit that it could have sold in the private market for $15.

Achieving Distributional Equity with Price Mechanisms

As mentioned above, the direct effect of a carbon tax or a cap-and-trade system on the distribution of income would be similar. An upstream carbon tax applied to producers of coal and natural gas and oil refiners would likely be passed on to consumers in the form of higher prices for these commodities. As a result, the price of energy—and any product that uses energy for its production or transportation—will go up. Similarly, the cost to firms of using permits would be embodied in the price of final goods. In either case, the new equilibrium would have higher energy prices and lower energy consumption.

Metcalf (2007) estimates that a carbon price would represent a much higher fraction of income for a low-income family than for a high-income family. A $15 per ton CO2 tax would reduce disposable income for the lowest-income households by 3.4 percent and for the highest-income households by only 0.8 percent. Metcalf proposes remedying this problem with an income tax credit against the first $560 in payroll taxes. This progressive tax cut would offset the regressive carbon tax and maintain broad distributional neutrality: while families would pay more for electricity and gasoline, these higher energy prices would be offset by lower taxes.

Even with this solution, however, the carbon tax would still make some groups better off and other groups worse off. Families with no workers, for example, would not receive the income tax credit. The tax swap would thus disproportionately affect people with disabilities, retired workers, and unemployed individuals. Although higher energy prices would result in automatic CPI adjustments to public benefits, additional steps would be needed to protect vulnerable families from increasing costs. Metcalf (2007) analyzes variants on his income tax swap proposal that include expanded Social Security benefits and lump sum transfers. He demonstrates that the latter two alternatives would do an even better job of achieving distributional neutrality than the tax swap. The Center on Budget and Policy Priorities has also begun extensive work on finding ways to protect the most vulnerable families from the price effects of climate change policies. They estimate that 14 percent of the revenues generated by a price mechanism would be needed to protect the most vulnerable low-income families, with much of the remainder needed to protect middle class families (Greenstein et al. 2007). Other consumers, such as those who drive more than average, would also be made worse off by a carbon tax.

A cap-and-trade system could have a similar process of compensation, provided that the majority of the permits were auctioned rather than given away for free. Stavins (2007) estimates that if all the permits were auctioned off, his proposal would raise $120 billion to $270 billion in 2015—enough to compensate families for higher energy costs. Stavins proposes allocating 15 percent of the permits for free to affected industries (in practice implemented as a 50 percent initial auction, with phasing in of a complete auction over 25 years). This 15 percent of free allocation is consistent with some estimates of the cost to industry from the proposal (Goulder 2004; CBO 2007), with the remainder of the cost borne by consumers. If more than 15 percent of permits were given away for free—or if a substantial portion of the auction revenue was used for purposes other than progressive tax cuts, benefit payments, or deficit reduction—then many families would be significantly worse off under a cap-and-trade system.

In addition to particular groups of consumers, certain industries and regions would feel the effect of the tax more acutely than others. A climate policy would create new jobs in new industries, but it would also destroy some jobs in older industries. Over the long run, the economy would adjust, but in the short run this transition could be disruptive to particular industries, such as coal mining, and particular geographic areas that are heavily dependent on these industries. Using a portion of the revenue generated by market mechanisms to compensate these areas and help them adjust to new, potentially higher-wage jobs in new sectors should be a critical component of any climate policy that aims to promote broad-based growth.

Carbon Tax vs. Cap-and-Trade

The discussion above stresses that carbon taxes and cap-and-trade are essentially identical under complete certainty. However, this equivalence unravels under the reality of considerable uncertainty about the costs of climate change and policies to mitigate climate change.

The price mechanisms also have important differences in political economy and implementation. This section highlights only the most important differences; Metcalf (2007) and Stavins (2007) have a much more extensive discussion. Getting the design details correct from the start is critical because any system, once put in place, is likely to persist for decades and will be difficult to change (Repetto 2007).

Optimal design under uncertainty. In a certain world, a carbon tax and cap-and-trade system would achieve the same emissions reductions at the same cost. If the government knew the exact response of consumer and producer behavior to price changes, it could pick a carbon tax to achieve a desired level of emissions reductions. Similarly, if it knew the optimal price of carbon, it could design a cap-and-trade system to stabilize permit prices at that target. In the real world, however, there is substantial uncertainty. This is especially true of climate change, for which there is pervasive uncertainty about the degree of the problem and the effect of mitigation policies on the problem. Neither scientists nor government fully understands the potential damages of climate change or the exact cost of various abatement approaches.

In a classic analysis, Weitzman (1974) shows that taxes are the optimal response under certainty about cost per ton, while tradable permits are the optimal response under certainty about quantity targets. In the case of climate change, the marginal benefit of emissions reduction is relatively similar across the feasible range of reductions, which suggests, according to Weitzman's analysis, that the optimal instrument under uncertainty is a tax.[9] Pizer (1997) applies this economic framework to GHG reductions and finds that the optimal tax policy generates gains that are five times higher than the optimal cap-and-trade policy. This is largely the result of permit price volatility in a cap-and-trade system, which could create market uncertainty and thus dampen investment.

In theory, as originally shown by Roberts and Spence (1976), the optimal policy is a hybrid between a carbon tax and a cap-and-trade system. In this hybrid system, the government would issue a limited number of permits and establish a maximum price for these permits. Once permits reached this maximum price, sometimes called a "safety valve" or an "alternative compliance fee" (Stavins 2007), the government would begin issuing more permits at this price to minimize price volatility. In the case of climate change, such a hybrid system would likely look more like a carbon tax—with the price frequently hitting the safety valve—than a cap-and-trade system.

It should be noted that the Weitzman-Pizer analysis assumes that the policy is not being adjusted. In reality, it would probably be adjusted over time. If, for example, a carbon tax was not achieving large enough emissions reductions, it could be raised. Or, if a cap-and-trade system resulted in permits that were too costly, then more permits could be issued. Thus, the economic difference between the two systems, even in the face of uncertainty, may not be as large as this analysis suggests.

Political economy risks. Given the similarity in these effects, the more important differences between carbon tax and cap-and-trade may in practice be political economy and implementation challenges.

One important question is which system is more likely to be adopted in practice, a consideration that is especially important because it is more efficient to act sooner rather than later. Currently, a cap-and-trade system has substantially more proponents among elected officials of both parties, and it was the model recently adopted in the European Union to curb carbon emissions.

Another important question is whether the political incentives to ensure proper design are the same for both. This distinction here is clear: a cap-and-trade system creates more political economy risks for distributional effects, while a carbon tax creates more political economy risks for efficiency effects.

Under a carbon tax, the consequences for consumer prices and thus family incomes would be relatively transparent. This transparency would increase political

9. What matters for climate change is the *specific* concentration of carbon in the atmosphere, which is a function of emissions over the past 200 years. As a result, in any given year emissions contribute only a small portion of the future concentration of carbon in the atmosphere. This means that the first and last tons of carbon emitted in that year result in similar amounts of damage, and thus should have a similar price, a goal that is best achieved through a fixed tax rather than tradable permits.

pressure for a carbon tax that is combined with progressive tax cuts to protect families from this harm, like Metcalf's proposed carbon tax swap. Although the distributional impact of a cap-and-trade system is identical to that of a carbon tax, the former is substantially more opaque. The public may mistakenly view a cap-and-trade system as a way to reduce emissions without raising prices since the cost of emissions is hidden in valuable permits. People may also believe that a cap-and-trade system puts more of the burden on industry since firms, rather than consumers, are directly subject to the limits. Moreover, to the degree that the burden on consumers is less transparent, there would be less political pressure to use the value of this scarce resource to compensate families. The industries that appeared the most affected, or those with the most political power, would lobby for freely allocated permits, a process that is not only unfair to consumers, but also inefficient and unproductive. Discussing the potential for political manipulation, Mankiw (2007) argues that a cap-and-trade system in which permits are given away for free "is equivalent to a tax on carbon emissions with the tax revenue rebated to existing carbon emitters, such as energy companies." In other words, he says, "Cap-and-trade = Carbon tax + Corporate welfare." A well-designed cap-and-trade system, especially one that phased in a complete auction of permits, could address these distributional concerns.

On the other hand, the political economy of carbon taxes lends itself to economic efficiency concerns. First, powerful or politically sympathetic sectors of the economy may be able to obtain exemptions from carbon taxes. The result would be a patchwork system in which emissions reductions would be limited to certain sectors of the economy rather than being undertaken by the people or firms that could do it at the lowest cost. As a result, the system would share some of the economic inefficiencies of command-and-control.

Once a price mechanism is in place, no additional command-and-control regulations or measures would result in lower emissions or a better climate. The only test for whether a command-and-control policy should be implemented is whether it would lower the cost of emissions reductions.

Second, constant political pressure to lower the tax may compromise the credibility of a carbon tax, diminishing its effectiveness. If decision makers did not believe the instrument would be in place in the future—or if they believed that taxes would go down or number of permits up—then they would not make the proper investment decisions for cost-effective emissions reductions. McKibbin and Wilcoxen (2002) show that this time-consistency risk can be avoided in a cap-and-trade system that allocates some long-term emissions permits to industry for free. Owners of these free permits would have little incentive to seek more future permits allocations because these allocations would depreciate the value of their permits.

Overall, a well-designed carbon tax and a well-designed cap-and-trade system would have similar economic effects. The two primary questions in deciding between them may therefore be "Which is more likely to be well-designed?" and "Which is more politically feasible?"

Price Mechanisms Plus Command-and-Control?

Finally, we consider the question of whether price mechanisms should be combined with command-and-control mechanisms. The most crucial insight into answering this question is that, once a cap-and-trade system is in place, no additional regulations or measures will result in lower emissions or a better climate.[10] Forcing firms and consumers to reduce emissions in one area would simply diminish the incentive for them to reduce emissions in another, perhaps more efficient, area. For example, if an emissions cap is set at 6 or 7 billion metric tons of CO_2, then no amount of CAFE standards, renewable portfolio standards, subsidies for hybrid cars, subsidies for ethanol, or investments in technology will result in emissions being lower or the climate being better, because total emissions would always be equal to the capped amount. As a result, any additional measures should be evaluated only by asking whether they lower the cost of achieving a given level of emissions reduction.[11] For this criterion to be fulfilled, the government must have the capability to do something with this command-and-control policy that the private sector cannot do itself.

In general, command-and-control policies do not meet this requirement, mostly because the government is at an informational disadvantage to the private sector. For example, with a price mechanism, electric utilities would consider the cost of carbon abatement in production decisions and determine the most efficient way to produce electricity while minimizing emissions. In contrast, a renewable portfolio standard that mandated a certain method of electricity production could not be less expensive than the most efficient system. Moreover, command-and-control policies could have other costs to consumers, in the form of higher taxes to pay for subsidies or higher costs to buy mandated consumer goods. For these reasons, the adoption of a price mechanism to reduce emissions or oil consumption should lead policymakers to be skeptical about approaches that made sense in the absence of a price mechanism.

There are, however, some specific cases in which the government may be able to help achieve a given emissions goal more cheaply. These possibilities include (1) helping individuals make more informed choices, (2) overcoming the problem of misaligned incentives between principals and agents, and (3) investing in research that the private sector would not have undertaken on its own. This subsection discusses the first two points, while Part 2 discusses the third point.

Policies that improve access to information on energy consumption may help firms and consumers find the most cost-effective abatement methods. Given information asymmetry in the electricity market, for example, requiring utilities to provide energy rate schedules, energy consumption calculators, or smart meters may increase consumer access to information and thus help consumers reduce emissions cost effectively. Similarly, improving and expanding the federal energy labeling programs would allow consumers to compare the energy efficiency of competing products.

However, improved access to information is unlikely to solve the principal-agent problem, even in the presence of carbon pricing. The principal-agent problem is one of misaligned incentives: in the construction sector, for example, home builders (the agents) have little incentive to promote energy efficiency because cost savings accrue largely to the building's tenants (the principals). The Lawrence Berkeley National Laboratory estimates that 35 percent of all residential energy is consumed by households affected by the principal-agent problem. In the immediate future, well-designed building codes and efficiency standards may be the only way to work around this market failure (Murtishaw and Sathaye 2006). In extreme cases such as these, command-and-control policies may serve an important role that price mechanisms cannot fulfill.

10. An obvious but not very realistic exception would be if the command-and-control measures were so stringent that, by themselves, they reduced emissions below the capped level. In this case, there would effectively be no market mechanism and thus all the problems discussed earlier would apply

11. An analogous argument holds for carbon taxes, although in this case the argument is that any given level of emissions reductions can be achieved by a specific carbon tax, while other regulations raise or lower the cost of achieving that reduction.

Part 2. Increase and Redirect Public Investments Focusing on Basic Research and Long-run, Speculative Technologies

New technologies will play a central role in addressing climate and energy challenges in a cost-effective manner. Many observers believe that, given the abundance of cheap coal in the United States, any viable climate solution must include technologies to burn coal more cleanly and capture and store carbon released during coal combustion.[12] However, as a recent MIT study on coal explains, large amounts of private or public research, development, and demonstration will be necessary to determine the commercial viability, reliability, and safety of this "carbon capture" technology (MIT 2007). Technological progress is also essential for helping the United States transition to a post-petroleum economy, a step that most importantly involves developing alternatives to oil in the transportation sector, where fuel choice is currently virtually nonexistent. In addition to these well-defined objectives, investments in technology should focus on high-risk, high-reward research such as innovative ideas for removing CO_2 from the atmosphere.

In general, the decentralized decisions of private individuals and firms should lead to economically efficient outcomes, *provided these actors have the proper incentives*. Ensuring that carbon and oil are priced correctly—either through cap-and-trade or taxes—is the most important incentive. These incentives would not just improve the utilization of existing energy sources and technologies—they would also serve as a major impetus for the private sector to invest in new technologies that improve energy efficiency, develop alternative fuels, or capture and store the carbon associated with fossil fuels. If a comprehensive price mechanism on oil and carbon were to be adopted, a large increase in private sector research into low-carbon and oil-efficient technologies would follow.

Even if carbon and oil were priced appropriately, however, the private sector would invest too little in research, for the reasons discussed below. As a result, society would have fewer options for addressing climate change and promoting energy security, making it more costly to achieve the reductions in GHG emissions and oil consumption envisioned under the price mechanisms discussed in Part 1 of this strategy. Conversely, climate research indicates that a combination of policies targeted at energy R&D and emissions pricing can reduce carbon emissions more cost effectively than emissions pricing alone, although the bulk of the reductions would still come from the price signal (see Fischer and Newell 2007; Goulder 2004; and CBO 2006b).

With the need for more research comes the need to refocus our existing research and technological investments on the basic research the private sector has less incentive to perform. In our current policy regime, where there is no price on carbon, it makes sense to adopt policies that subsidize certain technologies, such as hybrid cars. Although imperfect, these subsidies counteract the negative externality associated with the use of gasoline. Once carbon and oil are priced correctly, however, such policies are unnecessary because individuals and firms

12. The Hamilton Project papers by Metcalf (2007) and Stavins (2007), for example, use the MIT Emissions Prediction and Policy Analysis (EPPA) climate model, which makes the critical assumption that carbon capture and storage will allow the United States to continue using large quantities of coal.

will have an incentive to make the right choices about fuel efficiency. Therefore, if and when the United States adopts a price mechanism, it should also shift its technology policies to focus less on subsidizing particular technologies and picking winners and losers, and more on developing the basic research and long-run ideas that the private sector would not otherwise undertake. To fund this basic research efficiently, the government will also have to streamline its current funding process.

This transformation and refocus of energy R&D could be entirely paid for by redirecting existing subsidies that would be inefficient in an economy that priced carbon. Currently, the United States spends just $5 billion annually on energy research in areas like cellulosic ethanol, hydrogen storage, and carbon sequestration, while spending more than $14 billion annually on subsidies to energy-related activities, many of which are inefficient, environmentally harmful, or—in world with a price mechanism—unnecessary. Redirecting a portion of these subsidies to more basic long-run research would make it possible to double or even triple the existing energy R&D budget.

The Economic Argument for Federal Support for Energy Research

Even with a market-based price mechanism in place, there are several rationales for government investments in energy-related R&D. The most basic argument comes from the sizable economics literature showing that the social benefits of technological innovation often exceed the private benefits. That is because the benefits of innovation tend to spill over to other technology producers as well as to consumers—a phenomenon known as *knowledge spillover*. Several estimates show that innovators capture less than one-quarter of the total value of their innovations.[13] As a result, the private sector will invest less in R&D than is necessary for the nation to realize the full potential of technological innovations. This is particularly true in the case of energy research. Studies show that federal energy R&D investments have yielded substantial economic benefits and led to significant knowledge creation (see National Research Council 2001). In a recent study of 29 DOE-sponsored R&D programs in energy efficiency and fossil energy, the National Research Council found that these programs, taken together, yield annual rates of return of more than 100 percent. Direct technology policy is needed to help capture these high social returns. As Stanford economist Lawrence Goulder (2004) explains:

> Technology incentives can deal with the market failure created by firms' inabilities to capture all the returns on their R&D investments. Direct emissions policies (such as carbon caps or carbon taxes) can deal with the market failure created by climate-related externalities. Attempting to address the climate change problem with only one of these policy approaches cannot fully correct both market failures. (iv)

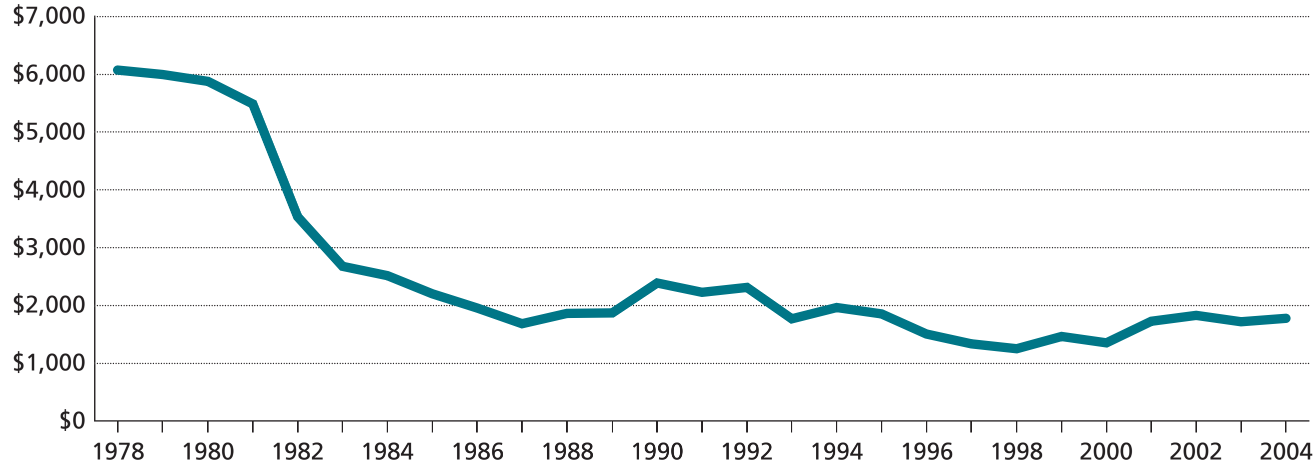
In addition to knowledge spillovers, there are at least four other reasons for government investment in energy R&D that apply specifically to the climate and energy security challenges. First, the enormous uncertainties surrounding the future impacts of climate change limit and thus reduce the likely returns to R&D investment. Even if the price of carbon were set to account for more certain environmental externalities, there may be little incentive to invest in the types of high-cost technological solutions that would be needed in the case of catastrophic climate effects (Jaffe et al. 2004). Absent

Pricing carbon and oil will generate significant innovations in energy efficiency and alternative fuels, but market failures in the technology sector indicate that additional support is needed to capture all of the social benefits from energy R&D.

13. One recent survey of the literature shows private investments in R&D have social rates of return between 30 and 50 percent, and private rates of return between 7 and 11 percent (Popp 2004).

FIGURE 1

Total DOE Energy RD&D Investments 1978-2004 (billions of 2000 dollars)



Source: Belfer Center (2007).

government policy, for example, firms are unlikely to invest in costly research for highly uncertain—yet potentially enormously valuable—solutions to climate change, such as removing carbon from the atmosphere, seeding the ocean to absorb more carbon, or launching mirrors into space to deflect sunlight. With the private sector unlikely to invest in these uncertain and costly endeavors, only government funding can facilitate their development into viable climate technologies.

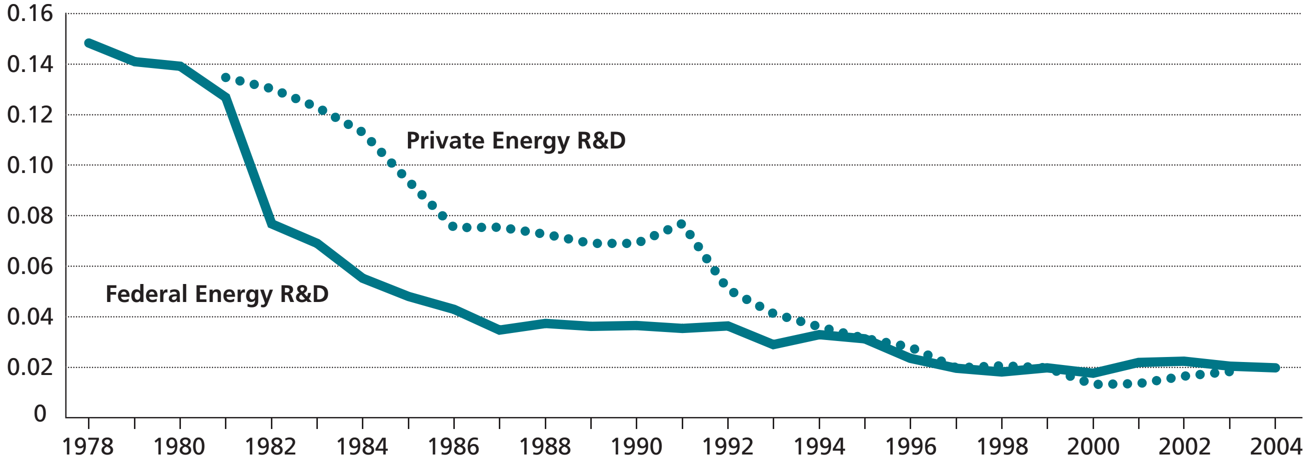
A second, related problem is that the market value of climate innovations depends on the stability of long-term government policies. If government commitments to raise the price of carbon are not credible, and market actors believe the government may relax its emissions caps over time, the incentive to invest in expensive energy R&D in the short term will be severely curtailed. There are various reasons that the government might reduce the announced price of carbon in the future. Most obvious, perhaps, is potential political pressure to reduce taxes in response to rising energy prices or some other economic shock. But another reason is that a new technological breakthrough could dramatically reduce atmospheric concentrations of carbon, making future emissions less dangerous. The government may reduce the price of carbon to reflect the lower marginal damage of future emissions (CBO 2006b).

Third, as discussed in detail later in this paper, climate change is a global commons problem, in that carbon emitted in another country contributes just as much to climate change as carbon emitted in the United States. Successful domestic R&D efforts, whether funded by the private or public sector, could lower the costs of reducing carbon emissions in other countries as well as in the United States. Technology transfer to other nations could create large positive externalities that would justify government investment in energy R&D.

Finally, there is extra reason to support energy R&D given the energy security challenge. Compared to carbon, pricing oil "correctly" may be more difficult, making it less likely that the government will send a strong enough price signal to induce innovations. Pricing carbon enjoys two advantages. First, despite the major uncertainties involved in measuring potential climate impacts, much work has been done to analyze the costs and benefits of each incremental carbon reduction. Second, the long-term nature of the climate issue means that policymakers can adjust the price of carbon as more information becomes available. Neither of these advantages exists with regard to the oil problem. Many energy security costs are geopolitical, not economic, and so are extremely difficult to measure in dollar terms. In addition, the energy security problem is immediate. The United States cannot afford to delay the pricing of oil until researchers determine the optimal price and consumption level. This difficulty in justifying and implementing the right market mechanism for oil makes a strong argument for federal support of energy R&D. Several technologies at

FIGURE 2

Declining Federal and Private Energy R&D Investments (percentage of GDP)



Source: Belfer Center (2007); National Science Foundation (2007).

various levels of development could completely transform the way the United States uses oil, especially in the transportation sector, which accounts for 70 percent of oil consumption (EIA 2007c). Here, government support for energy research could take center stage in moving toward a post-petroleum economy.

Current Funding for Research

In recent decades, both public and private energy R&D have declined, despite an increase in the magnitude and urgency of the energy and environmental challenges. Although Department of Energy R&D expenditures have risen slightly in recent years, they have only returned to the funding levels of the early 1990s, which is still less than one third the DOE energy R&D spending in the late 1970s (Figure 1). As a share of GDP, federal energy R&D declined from 0.15 percent in 1978 to 0.02 percent in 2004 (Figure 2).

At the same time, private energy R&D investment declined from 0.13 percent of GDP in 1981 to 0.02 percent in 2003 (Figure 2). However, the sharp increase in private sector venture funding for the energy sector in the past few years indicates that this decline may be reversing itself. Hundreds of start-ups have formed in fields from biofuels to batteries. New Energy Finance Ltd., a London-based research firm that specializes in alternative-energy investments, recently released a report (2007) stating that private-equity funds and venture capitalists invested $18.1 billion in the clean energy sector worldwide last year, a 67 percent increase over 2005 and much higher than government spending on energy R&D. That report estimates that worldwide private equity and venture capital investments in clean energy will grow at a compound annual rate of approximately 17 percent through 2013.

A Federal Energy R&D Strategy

Developing a federal R&D strategy for energy is critical. Various competing proposals have been advanced, including one by Richard Newell in a forthcoming Hamilton paper and another by Peter Ogden, John Podesta, and John Deutch (2007). Whatever specific details policymakers decide on, the focus should be to shift federal funding toward the kind of pure research that the private sector has little incentive to pursue. Commercialization projects should be left to the private sector, which has the willingness to invest in them and the motivation to choose wisely. To make the best use of federal resources, policymakers should consider the following elements of an effective R&D strategy:

First, the federal government should reorganize efforts by creating an energy technology initiative for basic research into ideas with the potential for eventual commercial application. To fund basic research in a targeted and efficient manner, the federal government will need to streamline its current energy

R&D funding, a process that has proven difficult within the existing DOE organizational structure. A Council on Foreign Relations task force argues that the current federal R&D effort is too fragmented and unfocused (CFR 2001). Reorganizing and streamlining federal efforts would become even more important if the government scaled up funding.

Some experts have recommended a dedicated agency focused on innovative energy technology research modeled after the successful Defense Advanced Research Projects Agency (DARPA)—to be called ARPA-E. As described by the National Academy of Sciences, ARPA-E would "sponsor creative, out-of-the-box, transformational, generic energy research in those areas where industry by itself cannot or will not undertake such sponsorship," and "would be designed as a lean, effective, and agile—but largely independent—organization that can start and stop targeted programs based on performance and ultimate relevance" (Committee on Science, Engineering, and Public Policy [COSEPUP] 2007, 154).

However, DARPA may not be the best model for energy R&D. As Ogden, Podesta, and Deutch (2007) point out, DARPA focuses on performance rather than on the cost of technologies. In contrast, the goal of an energy technology initiative would be to develop technology in a manner that is mindful of its potential for widespread use. The authors note that an energy technology initiative would differ from previous large-scale government innovation initiatives such as the Manhattan Project and the Apollo Project. The goal of these military endeavors was to accomplish specific goals like creating a nuclear weapon or putting a man on the moon. With government as their single dependable consumer, these projects could proceed unfettered by considerations of cost or commercial viability. In contrast, the goal of public research in energy technology is to help the private sector develop a range of technologies that are consistent with market demand and commercial viability. Reorganized federal R&D efforts should thus include mechanisms to transfer the government's basic research into the hands of private companies that can make the decision to commercialize it.

Cellulosic ethanol technology is one example of an area with potential commercial application that would benefit from basic, long-term research. Like corn-based ethanol, cellulosic ethanol is a substitute for gasoline. However, cellulosic ethanol would have significantly lower greenhouse gas emissions and displace far more gasoline than conventional ethanol, partly because the cellulosic process uses the entire plant while corn-based ethanol uses just the kernels and disposes of the rest. The private sector is close to developing first-generation conversion methods for cellulosic ethanol, but basic research into plant genetics and enzymatic processes would improve the efficiency and environmental benefits of this fuel.

In such areas of interest, government support should be concentrated where private firms are most likely to underinvest: in the basic research needed to develop the fundamental scientific ideas underlying these technologies.

Second, federal efforts should also invest in highly speculative areas. The type of R&D in which the private sector will most underinvest, and for which, concomitantly, there is the strongest need for government R&D spending, is exploratory research, the sort of blue sky, long-term research for which no commercial application may be apparent. One example is the prize idea set forth by Richard Branson and Al Gore for a technology that can remove one billion tons of carbon dioxide from the atmosphere annually. Since carbon dioxide removal is a public good, research into this area would probably fail to attract private-sector investment despite its enormous potential. Another area of speculative research is geoengineering, the promising but somewhat controversial study of transforming the Earth's surface and atmosphere to slow climate change. Ideas include seeding the ocean to absorb more carbon and launching particles to improve cloud reflectivity. Despite the need for caution, these ideas, if proven effective, could have benefits that vastly outweigh the relatively small costs of the associated research. Like national defense or public infrastructure, these technologies would have to be provided by the government, making federal funding necessary to facilitate research into these high-risk but potentially high-reward public goods.

Third, federal efforts should be scaled up, but in a manner that is mindful of diminishing returns. Taken together, declining federal R&D funding and high social rates of return for R&D clearly indicate that more federal research funding is needed. But the government should be aware that increased federal energy R&D spending will see diminishing marginal returns, meaning that every additional dollar spent on research will yield less benefit and fewer results. Moreover, there are costs associated with increasing federal support for energy R&D too rapidly without building the institutional mechanisms and infrastructure to support that research.

The optimal trajectory of research is difficult to estimate. Duke University professor Richard Newell argues in a forthcoming paper from The Hamilton Project that no more than $7 billion annually could usefully be spent on federal energy R&D. The National Academy of Sciences proposes funding ARPA-E at $300 million for the initial year and rising to $1 billion after five years (COSEPUP 2007, p. 154). Nemet and Kammen (2007) argue that federal R&D spending of $10 billion to $15 billion a year over 10 years would be sufficient to stabilize emissions levels even in the absence of any market mechanism. Finally, even the *Stern Review*, which calls for drastic action to avert climate change, finds that the optimal level of global R&D spending is only about $20 billion a year (Stern 2007).

Fourth, the best way to fund increased federal research funding is not by searching for new sources of revenue, but by redirecting expenditures on counterproductive or superfluous energy subsidies. The federal government spends $14 billion annually—more than $110 per household—on subsidies for energy-related activities, which is more than double the current $5 billion research budget. Certain reforms to repeal or redirect these subsidies could result in a doubling or even tripling of the current research budget.

These subsidy reforms fall into two categories. The first includes "win-win" policy reforms to repeal subsidies that both hurt the environment and distort economic choices. As shown in Table 3, the government could save $9 billion by pursuing win-win policies such as the following:

- **Cutting tax expenditures for coal, oil, and gas.** Numerous government policies support the coal, oil, and gas industries through the tax code. While the average effective tax rate on corporate investment is 26.3 percent, the Congressional Budget Office estimates that the effective tax rate on investments in mining structures is 9.5 percent, and in petroleum and natural gas structures just 9.2 percent, the lowest of any industry (CBO 2005). In particular, there is little justification for three of the most costly fossil fuel tax expenditures: the expensing of exploration and development costs, percentage depletion, and the alternative fuel production credit. Cutting these expenditures would raise around $4.1 billion a year, reduce distorted investment choices, and cut carbon emissions.

- **Better managing royalties from oil and gas.** Royalties paid by oil and gas companies are under-priced and often go uncollected. According to the Government Accountability Office, the federal government receives one of the lowest royalty payments of any government in the world (GAO 2007). Audit collections by the Department of the Interior are at an all-time low since it cut its auditing staff by 26 percent between 2001 and 2006 (POGO 2006). Meanwhile, a major clerical error by its staff in the late 1990s has already cost the government $1 billion and could cost around $2 billion a year for the next five years if it is not fixed.[14] Reforming the way the government prices and collects oil and gas royalties would raise revenue and lead to reduced carbon emissions.

- **Eliminating the subsidy for employer-provided parking.** The federal tax exemption for employee parking expenses is currently greater than the exemption for mass transit expenses. Since driving emits almost three times more carbon than mass transit per passenger mile, the higher parking deduction may worsen climate change and exacerbate congestion, traffic accidents, and local pollution. Eliminating this tax subsidy for parking would mitigate these problems and recover $2.9 billion per year.

- **Ending subsidies for private planes.** Small and private planes produce more than four times as many GHG emissions per passenger mile as large commercial airliners. Moreover, they contribute just as

14. Edmund L. Andrews, "Report Says Oil Royalties Go Unpaid," *New York Times* online edition, December 7, 2006.

> much, if not more, to the rising congestion delay at airports, which means more irritated passengers and lost productivity (Robyn 2001). To make these planes and jets pay fees commensurate with the costs they impose, airports should replace weight-based landing fees with congestion fees that vary by time of day (Brueckner 2004). Increasing charges for small and private aircraft would reduce airport congestion and GHG emissions by curbing demand.

In addition, a second set of subsidies for environmentally beneficial activities should be examined closely to see if they are still necessary in an economy that prices carbon and oil. Subsidies that should be reexamined once carbon and oil are priced, including tax credits for renewable energy, total $5 billion annually.

Table 3 shows the current allocation of the $19 billion annually spent on energy research and subsidies, much of which could be put to more efficient use by cutting counterproductive policies and programs and those that are unnecessary under carbon pricing. Reallocating this funding to more promising areas could eventually lower the cost of reducing GHG emissions and achieving energy security.

Finally, public policy should use prizes, tax reform, and patent reform to encourage private innovation. In addition to direct research funding, federal policy should also be geared toward encouraging the private sector to undertake more research focused on important social goals, such as reducing carbon emissions. The most important step in this regard, of course, is putting a credible and increasing price on carbon, a step that would unleash private-sector ingenuity in developing cost-effective ways to reduce emissions. Several other steps, however, would also help.

In recent years, interest has grown in the use of prizes to spur technological innovation (NRC 2007). As discussed in a recent Hamilton Project discussion paper (Kalil 2006), prizes have several potential advantages over grants. First, they allow government to pursue a technological goal without deciding in advance which researchers or methodologies are best positioned to meet the goal. Second, prizes are awarded only in instances of success, eliminating the incentive to exaggerate the prospect of success. Finally, prizes can attract participation by small groups and individuals who would not otherwise do business with the federal government. Energy and climate change policies are particularly ripe for the use of prizes, especially after the Energy Policy Act of 2005 authorized the DOE to increase its use of prizes. Kalil proposes that the DOE use this mandate to encourage the development of renewable energy and energy-efficient innovations. An excellent example from the private sector is the $25 million prize established by Al Gore and Richard Branson for the development of a technology to extract at least one billion tons of carbon from the atmosphere annually.[15]

The current research and experimentation tax credit also plays an important role in encouraging research. Overall, econometric studies have found that the tax credit has been effective in the sense that private sector research spending has increased roughly one-for-one with each dollar of tax credit (Newell forthcoming; Hall and Van Reenen 2000). R&D tax credits also have the advantage of supporting R&D investment while leaving to the private sector specific decisions about which technologies are most promising. Deferring to the private market obviates the need for government to pick "winners" and "losers." The credit, however, is hampered by uncertainty about its future (it is typically extended for only one or two years) and other design features that could be addressed by making the credit permanent and reforming its delivery.

Finally, patent protection reform would help address the problem of knowledge spillovers and encourage private-sector investment. By granting intellectual property protection, patents provide innovators with some assurance that they will be able to recoup their investments in new innovations. Indeed, the granting of intellectual property rights is the only policy instrument expressly ordained in the U.S. Constitution for the purpose of promoting innovation. Our current patent system, however, is overwhelmed and inefficient, increasingly awarding overbroad or unmerited patents. Numerous reform options have been proposed in response, including one in a recent Hamilton Project discussion paper (Lichtman 2006) that calls for extending "presumption

15. See "Branson launches $25m climate bid," British Broadcasting Company (BBC), February 9, 2007.

TABLE 3

Federal Expenditures Related to Climate Change and Energy

	Expenditures (millions in FY 2007)
Current Federal R&D Funding	
Climate Change Science Program	$ 1,822
Climate Change Technology Program	3,441
Examples	
Hydrogen Storage	35
Low Wind Speed Technology	12
Solid State Lighting	30
Cellulosic Biomass -Biochemical Platform R&D	33
Transportation Fuel Cells	8
Nuclear Hydrogen Initiative	19
Advanced Fuel Cycle/Advanced Burner Reactor	167
Sequestration	105
Integrated Gasification Combined Cycle (IGCC)	59
Subtotal	**5,263**
Policies that Hurt the Economy & the Environment	
Tax subsidies for oil, gas and coal production	1,840
Alternative fuel production credit[1]	2,370
Exclusion of reimbursed employee parking expenses	2,890
Unpaid royalties from oil and gas[2]	2,000
Subtotal	**9,100**
Other Subsidies For Energy-related Activities	
New Technology credit (PTC)	590
Tax credits for using energy efficient technologies	990
Ethanol & bio-diesel subsidies	3,220
Other	170
Subtotal	**4,970**
TOTAL	**$19,333**

1. Anecdotal evidence shows most of this credit goes to carbon-based fuels such as oil produced from shale and tar sands, but a small portion goes to renewable fuels such as gas from biomass. The tax expenditure on renewables best falls under the "unnecessary programs once carbon is priced" heading, but disaggregated data is not available.
2. This number only counts the yearly revenues lost from omitting maximum price clauses in 1998 and 1999. It does not include revenue-loss estimates from underpricing or under collecting of royalties.

Source: OMB (2007a) and (2007b); Andrews (2006).

of validity"—a legal doctrine that obligates courts to enforce patents—only to those patents that undergo a more intensive review. Of course, while patents encourage innovation in the long run, they can raise the price of innovative technologies and reduce use of the technologies in the short run. The government should keep in mind these limitations when considering patent laws, especially since they could limit crucial transfers of low-carbon technology to the developing world.[16]

16. Patent reform bills, S. 1145 and H.R. 1908, both titled "Patent Reform Act of 2007," are currently being considered by Congress.

Part 3. Lead by Example and Engage Major Emitting Nations in an International Response to Climate Change

Unilateral action to reduce U.S. oil consumption can counter major energy security problems, including macroeconomic adjustment costs, constraints on foreign policy by petro-states, popular resentment of U.S. presence in the Middle East, and the drain on military expenditures from that presence. Some have argued that even the erosion of civil liberties in oil-wealthy countries could be mitigated if the United States reduces demand enough to depress world oil prices.

However, in the case of climate change, international engagement is essential. Even if the United States pursues the course advocated in Parts 1 and 2 of this strategy by putting a price on carbon emissions in combination with well-targeted energy R&D investments, the results would fall far short of what is needed for cost-effective climate change mitigation. Instead, the biggest benefit of U.S. actions could be to help bring the major developing nations, and eventually the entire world, into the process of carbon abatement.

There are three reasons that a global response is essential for climate change. First, the developing world will soon surpass the United States and other developed nations in its contribution to global carbon emissions. Developing countries will account for fully three-quarters of the growth in global emissions over the next quarter century, with China alone accounting for 39 percent of this increase (IEA 2006). This increase in emissions will largely result from soaring energy demand in the developing world (see Figure 3). The International Energy Agency predicts that China will surpass the United States as the world's largest GHG emitter in 2009, a decade earlier than previously expected (IEA 2006).

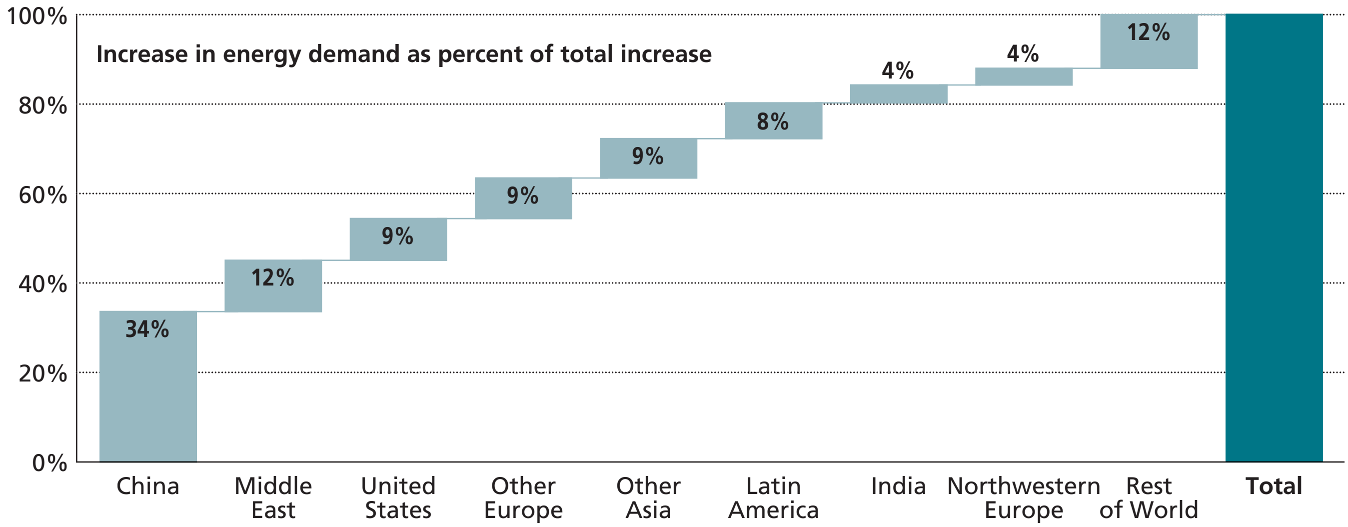
Second, involving the developing world will offer the greatest opportunity for low-cost emissions reductions (Olmstead & Stavins 2006; Watson 2001)—reductions for which these countries could potentially be compensated. The flip side of the global nature of climate change is that it does not matter where emissions are reduced; one ton of carbon abatement has the same environmental effect whether it takes place in the developed world or the developing world. It makes sense, then, to undertake abatement in the developing world, where rapid increases in demand for energy can be met at low cost by designing new power plants and technology to be more energy efficient. In the developed world, where energy demand is not projected to increase as much, reducing emissions would entail a costly process of retrofitting current infrastructure with cleaner technology (Frankel 1999).

Third, the effectiveness of measures by the United States to mitigate GHG emissions may be dissipated by so-called carbon leakage if other countries do not follow suit. Emissions reductions in a country that prices carbon could be partly offset as energy-intensive industries relocate to other countries, such as those in the developing world, where companies can emit carbon at no cost (Weyant and Hill 1999; Aldy et al. 2003). The result is that these countries are pushed onto increasingly carbon-intensive growth paths, making it that much more costly for them to reduce GHG emissions in the future. For these reasons, national and local governments are inherently limited in their ability to address climate change absent international cooperation.

The challenge, then, is to engage major emitting nations, especially those in the developing world, in cli-

FIGURE 3

Increase in Energy Demand by Region, 2003-2020



Source: McKinsey Global Initiative (2007).
Other Europe includes Baltic/Eastern and Mediterranean Europe and North Africa. Other Asia includes Australia and Korea.
Global increase in demand is 191 quadrillion British thermal units (QBTUs). Percentages may not add up to 100 because of rounding.

mate change mitigation efforts. Achieving this goal is complicated by considerations of economic efficiency, which requires low-cost abatement in the developing world, and distributional equity, which demands action from rich nations historically responsible for emitting GHGs. These conflicting considerations are evidenced in the arguments from both sides about the allocation of responsibility for GHG reduction.

Developing nations do not want to be bound by emissions targets because, they argue, they have more immediate and pressing national concerns, such as economic growth and poverty reduction. Moreover, they argue, the current climate crisis was created because developed countries chose to pursue "dirty" industrialization paths, and developing countries should not bear the burden of repairing that damage. In addition, developing countries may feel that their best defense against climate change is to industrialize quickly and move away from an agricultural economy, which is far more affected by climate change than economies based on manufacturing and services. This focus on industrialization may make developing countries less willing to bear the costs of reducing emissions.

Developed countries, meanwhile, do not want to undertake costly GHG reductions unless developing countries commit to future reductions. They fear putting a greater burden on firms and workers already feeling pressure from lower costs and wages in emerging nations. Moreover, they argue, the bulk of GHG emissions is projected to come from the developing world in the coming years, so any solution to the climate change problem must include those countries. In addition, some argue, developing nations stand to benefit most from climate change mitigation efforts and should therefore bear some of the cost of these efforts. As noted above, agricultural economies like those found in the developing world are more vulnerable to drought and flooding, as are large populations living in low-lying areas. A doubling of GHG concentrations would cost developing countries 2 to 9 percent of GDP, but would cost developed countries only 1 to 1.5 percent (Cazorla and Toman 2000). Finally, developed countries point out, as noted above, that it is more economically efficient to reduce emissions in the developing world.

These tensions were fully evident 10 years ago as the Kyoto Protocol was negotiated. The Protocol set ambitious near-term emissions targets for industrialized countries with policy mechanisms designed to facilitate cost-effective implementation, but exempted developing countries from its requirements. Specifically, the

Protocol established emission commitments for industrialized countries for the 2008–2012 timeframe, and created tradable emission allowances for industrialized countries with targets that would serve as the basis for an international emissions market. The agreement also established the Clean Development Mechanism (CDM) to allow developed countries to generate emissions reductions in developing countries to offset their targets.

Ten years after its creation, the Kyoto Protocol has been praised in some respects and criticized in many others (Aldy and Stavins 2007). On the one hand, it attempted to build in cost-effective market mechanisms to encourage spatial and temporal flexibility in emissions reductions. On the other hand, some of the world's largest GHG emitters, notably China and India, were exempt from the Protocol. Moreover, the Protocol required steep cuts in a short timeframe, while climate change is a long-term problem best addressed with gradually escalating emissions targets over a long period of time (Olmstead & Stavins 2006). The Protocol lacked tough enforcement provisions, evident from the fact that most participants are well above their targets even as the 2008–2012 commitment period approaches. Finally, the CDM has resulted in substantial payments for emissions reduction that would have happened anyway, or that could have been achieved at negligible cost.[17]

There is broad recognition that new intellectual and political energy is needed to develop a successful post-Kyoto international policy architecture that learns from these lessons and that reconciles the myriad tensions inherent in climate policy. There is vast disagreement about what such a policy architecture should look like, with some calling for multilateral targets and timetables, others for harmonized domestic actions that focus on national and even regional institutions, and still others for coordinated and unilateral policies that allow countries to experiment with different policies and learn from one another.[18] Each of these approaches has merit, and a full assessment of the advantages and disadvantages of each is beyond the scope of this paper.[19] Whatever international policy architecture emerges, however, three steps should clearly be taken now to address the global commons nature of the climate change problem.

First, the United States should help encourage the major developing countries to act by setting an example through the unilateral adoption of measures to curb GHGs. It is critical that the United States, at long last, show real leadership on this issue. As long as other nations see inaction on the part of the richest nation in the world (and contributor of one-quarter of all global GHG emissions), they have a much stronger case for not taking substantial actions themselves. Climate change is a situation in which leading by example is not just idealistic rhetoric, but is also likely to be a more effective policy. The United States should be willing to take unilateral action now to facilitate multilateral action later.

Of course, the United States may rightfully be concerned that other nations will free ride off its emission reduction policies, that pricing carbon will simply cause carbon-intensive industries to relocate to other countries, or that raising business costs from pricing carbon will put U.S. firms at a competitive disadvantage. But the continuation of business as usual is not an acceptable response to these valid concerns. One solution might be to tax imports based on their carbon content just as carbon in the United States would be taxed or otherwise priced through the creation of a cap-and-trade market. Such a carbon tax on imports would apply not only to the carbon they emit on consumption in the United States (e.g., a car's emissions), but possibly also to the carbon emitted during production (e.g., in the making of steel), although the permissibility of this latter approach is more questionable under World Trade Organization (WTO) rules. Taxing imports may encourage other nations to price carbon themselves, since they would then be exempt from paying an import tax to the United States and would keep the revenue generated by such a tax. Other nations have proposed this type of approach. France, for example, is considering a proposal

17. Lawrence H. Summers, "We Need to Bring Climate Idealism down to Earth," *Financial Times*, April 29, 2007.
18. For a full discussion of each of these approaches, see Aldy and Stavins (2007).
19. Such an effort is incredibly important, however, as is evident from the $750,000 the Doris Duke Foundation recently gave to Harvard University to study precisely this question.

to impose a carbon tax on imports from countries that do not price carbon by 2012.

Second, the United States should focus on building a broad-based coalition of major emitting nations to tackle climate change over time rather than encouraging steep near-term emissions reductions from a few countries. Since carbon stays in the atmosphere for up to 200 years, reducing emissions 10 years from now has the same environmental effect as reducing emissions today. What is important, however, is that all major GHG-emitting nations commit to an eventual reduction in emissions. To create incentives for other countries to join its efforts, the United States may consider following the lead of the EU, which recently committed to reduce GHG emissions by a certain amount and agreed to lower its target even further if other industrialized nations followed suit.[20] This strategy, which treats climate negotiations as an iterative process, is a more transparent version of the approach some have advocated of using unilateral action to encourage international cooperation. Nations that act first to mitigate emissions can ratchet up their activities as they see other nations follow suit, or threaten to abandon their efforts if other nations fail to follow suit (Pizer 2006).

Todd Stern and William Antholis (2007) have floated a proposal to spur more international cooperation on global climate change. They note that much of the international process to date has involved more than 150 countries, resulting in a complicated and unwieldy system. While the truly multilateral process is important, they argue for the formation of an E8, "a compact forum of leaders from developed and developing countries devoting their full attention once a year to global ecological and resource challenges."

Finally, the United States should take active steps to assist developing countries to reduce their emissions. For example, investments in energy R&D can have technology spillovers that make new technology available to the rest of the world, allowing other countries to reduce emissions cost effectively. Funding the development of climate-friendly technology and making it available at low cost to the developing world would yield multiple benefits: it could reduce emissions in developing countries, which will account for the majority of future GHG emissions, while also placing responsibility with the developed world, which has contributed significantly to the climate problem.

Several potentially complementary approaches should be considered. Technology-oriented agreements with other countries could be used to achieve the goals of knowledge sharing and coordination (de Coninck, Fischer, Newell, and Ueno 2007). Jagdish Bhagwati proposes an international superfund, modeled after the Superfund program in the United States, which funds the clean-up of toxic waste sites by taxing industries that contribute to pollution.[21] In an international superfund, industrialized nations historically responsible for climate change would contribute to the financing of low-cost technology and other abatement efforts. Lawrence Summers proposes that the World Bank and regional development banks be reconstituted as the Banks for Development and the Global Environment, and take on as a major mission the provision of subsidized capital for projects that have transnational environmental benefits.[22]

Whatever its specific course of action, U.S. leadership is an essential prerequisite to any meaningful global action on climate change. Ironically, it is the global commons nature of this challenge that compels the United States to take unilateral action. Unless the rest of the world sees firm commitment from the world's wealthiest nation—also the world's biggest energy consumer and carbon emitter—it will be resistant to undertaking costly action itself, leaving climate change to remain a tragedy of the commons.

20. "EU Seizes Leadership of Climate Fight," *Financial Times*, March 10–11, 2007, p. 2.
21. Jagdish Bhagwati, "Global warming fund could succeed where Kyoto failed," *Financial Times*, August 15, 2006.
22. Lawrence H. Summers, "Practical Steps to Climate Control," Financial Times, May 28, 2007.

Conclusion

Developing a comprehensive approach toward climate change and energy security will require thoughtful design, political will, and recognition of the differences between these goals. The energy security problem is immediate, while the potentially greater problem of climate change will unfold over the course of decades and centuries. The goal of climate policy should not be to reduce emissions immediately and dramatically, but rather to ensure a gradual reduction in emissions. Phasing in reductions would give society the incentive to develop new technologies and the time to adjust capital stock appropriately.

The central component of this strategy must be to develop price signals that reflect the full climate and energy security costs of burning fossil fuels. The government should price carbon and oil through a cap-and-trade system or a tax and then allow competition and innovation to take hold, while taking steps to protect those families least able to absorb these higher prices. But the government also has an essential role that goes beyond simply setting up the price framework: it must make the proper investments in research, development, and demonstration, recognizing that cost-effective and commercially viable technologies are necessary to solve the climate and energy security problems. The federal government should focus its funding on basic research, especially in areas where the private sector has little incentive to invest, while also re-thinking how it manages and distributes those funds.

In developing its strategy, the United States must not lose sight of the global context of its domestic policies, especially those relating to climate change. Climate change is not the first global challenge to demand international cooperation—eradicating polio and reducing ozone depletion are relevant precedents—but it is unique in its disregard for national boundaries. Lack of resources or political will on the part of a few countries can dilute even the most concerted efforts by others to reduce greenhouse gas emissions. Strong commitment by the United States is likely to be the only impetus toward truly international cooperation. Any successful U.S. policy to address climate change and energy security must start with decisive action at home.

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