CLEAN ENERGY AND JOBS

A comprehensive approach to climate change and energy policy

by James P. Barrett and J. Andrew Hoerner,
with Steve Bernow and Bill Dougherty

ECONOMIC POLICY INSTITUTE

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1. INTRODUCTION

In the wake of rising energy prices, rolling electricity blackouts, threats to world energy markets, and ominous news of global climate changes, a broad consensus is emerging that the U.S. needs to improve its energy efficiency and diversify its sources of energy supply. Industry and workers realize that they need energy sources that are reliable and secure against international price shocks and domestic market manipulation. Consumers seek lower, more predictable energy bills. Environmentalists seek to reduce adverse impacts at every point on the fuel cycle, from extraction through combustion. Perhaps the most serious of these environmental concerns arises from the fact that fossil fuel combustion emits greenhouse gasses, gasses that most leading climate scientists believe cause global warming and climate instability.

Energy industries and others have argued that policies to reduce carbon emissions or promote new energy sources could impose debilitating costs on the economy. Some labor and consumer groups have also raised concerns that such policies have adverse impacts on low-income households,[1] on workers in particular industries, and on the economy as a whole. These concerns have been bolstered by a series of studies that portray grave economic consequences from policies to improve energy efficiency or reduce carbon emissions, especially when those policies are implemented through large increases in energy taxes without returning the revenue gained through cuts in other taxes.[2] Working people and consumers want both a strong economy and a clean environment, yet some approaches to climate and energy policy would hurt economic growth and bring these interests into collision.

This study assesses the impact of an alternative approach to climate and energy policy. Based on an extensive review of the literature and of the experience of other nations, it attempts to assemble a set of policies that would provide moderate but steady increases in energy efficiency and reductions in carbon emissions, while improving overall economic efficiency. It then estimates the macroeconomic impact of these policies. This alternative policy package has four main elements:

- a modest carbon/energy tax on major energy sources, with most of the revenues returned through cuts in taxes on wages;
- a set of policies to promote the development of new energy-efficiency and renewable energy technologies;
- policies to offset competitive impacts on energy-intensive industries; and
- transitional assistance to compensate any workers and communities harmed by the policies.

The policy package is self-funding in that the costs of the transition fund as well as the administration of the technology policies are paid entirely by the tax receipts it generates. The package is designed to minimize the burden on workers and consumers and provide help for those who would suffer if energy production were reduced. It is informed by a list of principles adopted by the Just Transition and Market Mechanisms Working Group of the Labor-Environment Dialogue on Climate Change. (See Appendix A for a discussion of these principles.)

The package modeled here stands apart from other studies in the U.S. literature in that it attempts to combine the best elements of a market-based approach, policies to promote investment and technology, competitiveness policies, and equity concerns. No previously published U.S. study has conducted a macroeconomic analysis of more than two of the four policy elements analyzed here.[3] Indeed, many studies include only the carbon charge without revenue recycling, and *none* of the other elements. This study is also unusual in incorporating the insights of engineering-based analysis of the potential of specific technologies into a macroeconomic model. Technology assumptions are taken primarily from U.S. Department of Energy models and studies.

The four policies were integrated and the results estimated using the LIFT model, a sophisticated 92-sector macroeconomic model of the United States built and operated by the Inforum research and consulting group at the University of Maryland. The model was first calibrated to the economic and energy assumptions used in the 2001 *Annual Energy Outlook* of the U.S. Energy Information Administration. The macroeconomic and sectoral forecasts of the baseline and policy package were then prepared for the period 2001-20, focusing primarily on the effects on gross domestic product, employment, energy security, and greenhouse gas emissions.

The macroeconomic results discussed here are generally more positive than previous studies that rely on a single-instrument approach. This outcome is compatible with both theoretical analyses (see Sanstad, DeCanio, and Boyd 2001) and previous modeling studies conducted in Europe that combine technology promotion and market-based approaches with revenue recycling.[4] Our results suggest that these policies have positive synergy. In particular, the combination of revenue recycling and "no-regrets" technology policy (i.e., policies to promote technologies that pay for themselves over time) accounts for the positive results on GDP and employment.[5] These policies, together with essential border tax adjustments described in section 1.3, help preserve the competitiveness of energy-intensive industries. As a result, we find that these industries would suffer much smaller losses than many previous studies suggest. Finally, this is the first U.S. study to perform an integrated analysis of the cost of providing transitional assistance to workers and communities harmed by climate policy. We find that such policies, though by no means free, can be fully funded using only a small portion of carbon/energy tax revenues.

Relative to the base case, we estimate that the policy package would have the following results:

- U.S. carbon emissions would decline by 27% in 2010 and by 50% in 2020. Other greenhouse gasses and pollutants would also decline.
- GDP would increase by a modest 0.24% in 2010 and by 0.6% in 2020.
- an additional 660,000 net jobs would be created in 2010, 1.4 million in 2020. This would increase employment in the service sector and reduce the rate of decline in employment in manufacturing.
- unemployment would fall and real after-tax wages would rise.
- oil imports in 2020 would fall from the baseline forecast by an amount slightly higher than total current U.S. purchases of oil from OPEC.
- household energy bills would fall in every year, by a steadily rising amount.
- the effect on income distribution would be slightly progressive.

However, these benefits do not come without cost. Employment in coal mining would suffer severely, amounting by 2020 to more then half of all jobs in the coal mining sector. There would also be declines in employment in electric and gas utilities that are numerically larger though smaller in percentage terms. Jobs would also be lost in the production of other fossil fuels and in the rail transportation of coal. Only a portion of this shrinkage can be absorbed by normal turnover. Extremely small job losses are seen in a few other industries that are either energy-intensive or are suppliers to the energy industries.[6]

The policy package provides every worker in an energy-producing or energy-intensive industry who loses his or her job with two years of full income replacement, including health and retirement benefits. It also provides up to four years of college education or other professional training and up to two additional years of income support for those who take more than two years of training or education. For some older workers, it provides the alternative of additional benefits as a bridge to retirement in lieu of education or training. For heavily affected communities, the package includes development assistance of $10,000 per job lost. We have attempted to estimate the number of layoffs that would result from the policy package and the cost of providing economic compensation and transition assistance to affected workers and communities. These benefits can be fully funded by the carbon/energy tax without substantially reducing the national economic benefit.

Overall, the results suggest four conclusions. First, the economic costs and benefits of a climate and energy policy depend critically on elements of the policy design. Specifically, costs are reduced and benefits enhanced by returning the revenue from carbon/energy charges through cuts in other taxes, and through more rapid introduction of new energy technologies; these two policies together can yield a net economic benefit. Second, the combination of technology promotion and well-designed policies to offset competitive burdens can reduce the harm to most energy-intensive industries to low or negative levels. Third, consumers and income distribution need not be harmed and can even benefit. Finally, substantial compensation can be provided to affected workers and industries without negating the general economic benefit.

Like all economic modeling efforts, this one has limitations based on simplifying assumptions.[7] These include economic and technical assumptions, as well as implicit political assumptions, e.g., that worker and community assistance programs will be adopted together with the necessary tax and energy policies. To the extent possible, all assumptions are explicitly stated, and the reader is encouraged to examine how realistic they may be.

We make no claim that the policy package described here is in any sense “optimal.” Instead, the policies are intended to represent a feasible approach, similar to but more modest than plans adopted in many European nations. The policy set analyzed here lies in the middle ground between those who would do nothing to address the economic and environmental risks of fossil fuel consumption and those who would insist on immediate solutions, heedless of economic or human cost. Our results suggest that we do not need to accept a choice between environmental degradation and economic calamity. This study is not intended to provide a definitive solution to the nation’s energy, economic, and environmental needs, but rather to advance the debate toward an approach that can better harmonize environmental, economic, and social justice goals.

1.2 Crafting an energy policy: environmental, security, economic, and equity goals

Energy policy has many diverse and sometimes contradictory goals. In this section we briefly discuss five of the goals of energy policy that informed this study: protecting the environment, improving energy security, strengthening the economy, preserving competitiveness, and distributing burdens and benefits as fairly as possible.

1.2.1 Protecting the environment

The consumption of coal, petroleum, and natural gas has introduced a number of unintended side effects throughout the world. Proposals to expand oil drilling may endanger sensitive natural habitats such as the Arctic National Wildlife Refuge. Coal is the nation's primary source of electricity, but is also the principal source of sulfur dioxide that causes acid rain, atmospheric mercury, and other pollutants. Combustion of fossil fuels is the principal source of air pollution and a number of other environmental problems. Many of these problems have been reduced through end-of-pipe controls and other measures over recent decades. Overall air and water quality have improved by some measures, and a number of serious environmental problems – e.g., atmospheric lead – have been virtually eliminated.[8] However, other problems have proven more intractable, and continued economic growth, while good in itself, can lead to increased environmental impacts even when emissions (or other damages) per unit of output are declining.

One central example of such a problem is global warming. The vast majority of the world's leading scientists now agree that human-induced emissions of greenhouse gases – most notably carbon dioxide, a necessary by-product of fossil fuel combustion – are trapping extra solar heat, with potentially catastrophic worldwide consequences.[9] Ongoing events such as the recent string of years with record-breaking average temperatures and the thinning of glacial and polar ice make clear that this is a problem that will become increasingly urgent over time. A substantial reduction in fossil fuel consumption will be necessary if the U.S. is to significantly curtail greenhouse gas emissions and other environmental problems.

This report did not set any particular target or goal for emissions reduction. Instead, the goal is to assemble a feasible, cost-effective package that achieves substantial energy savings and related environmental benefits, and puts aggregate emissions of major pollutants, including carbon dioxide, on a downward path for every major sector of the economy. To achieve this, the policy set examined here focuses on improvements in energy efficiency and increased use of renewable energy resources. In addition, it encourages the substitution of fuels with lower emissions of greenhouse gasses and other pollutants, such as natural gas, for those with higher emissions, such as coal.

1.1.2 Improving energy security

It is impossible to run a modern society without substantial amounts of energy. However, in recent decades energy prices have been extremely volatile, threatening the economic health of U.S. industries and households alike. Reducing consumption of oil, for example, would help to avoid the periodic economic instability that arises from fluctuations in world oil prices, which have contributed to two major U.S. recessions.[10] In a similar vein, more efficient use of electricity could help protect industry from the economic impacts of electricity price spikes such as those recently seen in California.

One goal of this project was to improve national energy security, and the policy package addresses this issue in two ways. First, we improve energy efficiency in all sectors in order to reduce the vulnerability of the economy by cutting the share of energy purchases in total industry costs and household budgets. Second, we expand the diversity of energy sources so that choice is increased and markets become more difficult to manipulate.

1.1.3 Strengthening the economy

A strong economy with increasing wages and low unemployment is vital to the well-being of workers and consumers. Previous studies have suggested that some approaches to reducing carbon emissions or increasing energy efficiency would reduce GDP, wages, and employment. This makes clear the need to focus attention on approaches to achieving energy efficiency gains and emission reductions that reduce economic harm or that provide a net benefit.

The goal of this study is to combine various elements of climate and energy policy that have been shown in other studies to reduce the economic cost or increase the economic benefit of achieving emissions reductions and energy efficiency improvements. The two most important of these are returning the revenue from a carbon/energy tax[11] through cuts in other distorting taxes and investing in new energy technologies. Competitiveness policies described in the next section also play an important role.

1.1.4 Preserving competitiveness

In an increasingly competitive global economy, it is necessary to account for the trade implications of any policy that could impose significant costs on firms producing traded goods. Conversely, policies that improve productivity may strengthen the economy and improve our competitive position. Manufacturing industries that produce traded goods tend to have above-average wages and are a vital part of the U.S. economy.

One source of the economic losses predicted by some other studies is a substantial deterioration in the trade balance. This trade impact occurs in large part because in those models the high carbon taxes assessed on domestically produced energy-intensive products are not assessed on competing goods produced elsewhere. This reduces competitiveness of these industries both domestically and abroad. As a result, these models project that U.S. producers are burdened by a significant additional cost that foreign producers are not, resulting in lost market share.

This problem is less pronounced in the results discussed here because of the relatively low carbon tax applied. In addition, this policy package, unlike most previously modeled, includes a border adjustment of the carbon tax for fossil-fuel-producing and energy-intensive industries. The border adjustment rebates the taxes paid by producers as their products leave the U.S. for foreign markets and imposes an equivalent tax on foreign products as they enter the U.S. This policy would help to keep the playing field level – both domestically and abroad – so that U.S. producers are not subjected to undue erosion of market share by firms located in countries that do not employ a carbon charge.

1.1.5 Distributing burdens fairly

It seems clear that ultimately something will be done to protect U.S. energy security, improve energy efficiency, and reduce U.S. greenhouse gas emissions. But what will such changes cost, and who will pay the bill? Will these problems be solved in a way that protects the interests of U.S. workers and consumers, or will workers and consumers be required to bear the brunt of the costs? Proposals to compensate industry and shareholders, but not workers, with marketable pollution emission trading rights have already been put forward by industry, government, and some environmental groups. These rights could be sold profitably by corporations, making it easier for them to get out of the energy-producing or -consuming business, regardless of the impact on their workers and consumers. Most current proposals, however, provide no parallel protection to workers and communities. Other climate and energy policies that put U.S. worker or consumer interests at risk have also been urged.[12]

Workers and consumers have been concerned that much of the burden of improving environmental quality would fall on them through increased prices on one hand or reduced employment on the other. In the past, workers and consumers have often found themselves shouldering a disproportionate share of the burden of environmental protection. More than once, this has put them in the unfortunate position of having to choose between preserving the environment and meeting their economic needs. The policy package modeled here is intended to avoid this conflict by achieving environmental goals while simultaneously ensuring that the costs and benefits of these efforts are shared as broadly as possible.

However, even the most cost-effective energy efficiency policies create both winners and losers in the near term. Some workers in fossil fuel industries, and perhaps other energy-intensive industries, could lose their jobs if policies to reduce the use of fossil energy are adopted. The severity of this problem depends in large part on how energy policies are designed. The injury to workers will be much smaller if the policies have been designed to help prevent such job losses where possible and, where it is not, ensure that these workers, their families, and their communities can land on their feet.

This report examines the fairness issue from two different perspectives. First, it looks at fairness in terms of income distribution. Some previous studies of other approaches to carbon reductions different from the one modeled here have reported negative impacts on low-income households and minorities. This highlights the need to consider distributional concerns when comparing alternative energy policies. One of the design constraints for this policy package was that it should not place a disproportionate share of the burden on low- and moderate-income households.

This report also examines equity from the perspective of workers in particular sectors. The first goal is to minimize the job impacts in energy and energy-intensive sectors that will result from energy efficiency improvements or emissions reductions. Thus, the package discussed here includes a range of policies to minimize job loss in these industries. For those workers who would lose their jobs, we estimate the cost of providing compensation sufficient to offset the average economic loss, with a goal of assuring that workers in a few sectors should not be made to shoulder the cost of achieving general social benefits.

Previous efforts to provide transitional assistance to workers have often been insufficient or ineffective. We have thoroughly reviewed the literature relating to past efforts to provide transitional assistance to individuals and communities harmed by economic change, in an effort to craft policies that would be workable and effective (Barrett 2001b).

1.2 Market-based and technology-based energy policies

1.2.1 Benefits of a combined approach

Various efforts have been made to determine the feasibility of reducing U.S. consumption of fossil fuels, often in the context of meeting the carbon reduction targets laid out in the Kyoto Protocol. Those that use macroeconomic models of the U.S. economy tend to rely on a single blunt instrument, like a carbon tax or other pricing mechanism, to achieve the desired reductions in fossil fuels or carbon emissions. Some of these studies predict serious negative consequences in terms of lost jobs and decreased GDP should the U.S. adopt policies to reduce the amount of fossil fuels it consumes.[13] A few of these studies appear to exaggerate the cost of such reductions, as they lack obvious cost-reduction components such as gradual phase-in of the tax or recycling of tax or permit revenues to offset other taxes.[14]

Studies of such policies can play a valuable role by demonstrating that certain approaches to climate and energy policy entail substantial economic burdens on society. For example, a report released by the Economic Policy Institute assessing the results of a modeling effort prepared for the United Mine Workers of America and the Bituminous Coal Operators Association found that the greenhouse gas policies modeled would “have a strikingly consistent, negative impact on real wages” and “could have significant costs for the economy.” That effort modeled a tradable carbon emission permit system aimed at reducing emissions to levels 10% below their 1990 levels by 2010 (a larger reduction than found here); permits were issued to industry at no cost, i.e., there was no return of the revenue through cuts of other taxes to businesses or workers, and there were no technology-promoting policies. That study found that the equilibrium carbon charge would rise to $270 per ton in 2010, resulting in GDP 2.5% below baseline (Scott 1997).

However, macroeconomic studies that examine the use of market mechanisms (such as taxes or tradable permits) to promote energy and carbon efficiency are virtually unanimous in finding that, for any given level of emissions reductions, reduced net costs or net benefits are possible if the revenues are re-cycled.[15]

In contrast to macroeconomic studies, studies using engineering-based models that examine the cost effectiveness of applying alternate energy technologies on a case-by-case basis generally find that a wide range of energy efficiency and renewable energy initiatives could be adopted at a relatively modest cost or a net saving.[16] Sometimes this approach represents a study of what is technically feasible rather than a forecast in the strict sense. When engineering models are used to do forecasts, they typically rely on multiple policy instruments rather than a single-instrument approach.

When the technical improvements in energy efficiency forecast by such models are cost-effective, they result in increased economic productivity and associated economic benefits. However, most engineering models are not designed to assess the economic impact of adopting policies and technologies when those impacts go beyond the level of the firms and industries adopting them, such as lost production in energy-producing industries. They therefore generally do not fully account for macroeconomic impacts and inter-market interactions. While they often find economic benefits from modest improvements in efficiency, there are some costs for which they cannot account, and they may thus overstate the benefits of the policies they model.

In this study, the aim is to wed the best elements of these different approaches into a single effort to assess the impact of a comprehensive set of policies designed to achieve substantial environmental gains as effectively and fairly as possible. There are several ways of viewing this result. First, as discussed in the next section, well-designed technology policies shift the production-possibilities frontier outward, thus making it possible to achieve more of both economic production and environmental quality. Second, technology policy gives businesses and consumers more alternatives in responding to price incentives, thereby reducing the cost of achieving any particular reduction. Finally, one can simply conclude that the combined benefit of the labor tax cut and the technology improvements outweighs the negative economic impact of the carbon/energy charge.

Specifically, in contrast to studies that rely exclusively on carbon charges to achieve reductions in emissions, we find that comparable reductions can be achieved when a much more modest carbon charge ($50 per ton as opposed to $100-$300 per ton) is applied in conjunction with policies designed to promote the adoption of energy-efficient technologies. Further, while other studies often predict large economic costs to achieving these reductions (GDP losses in the neighborhood of 0.5-1.5%, with some studies finding losses as high as 3%), the results here find modest macroeconomic gains resulting from this policy set, gains that in the aggregate substantially outweigh the losses forecast for a few sectors.

1.2.1 How technology policy works

The fact that this study finds that there are economic gains to be had by increased adoption of existing technologies might seem to imply that businesses and consumers are ignoring or unaware of potentially profitable investments. But this is not the case. Rather, the primary source of the economic benefits we find from technology policy is an acceleration of the currently occurring rate of energy efficiency and productivity improvement through additional research and coordination of private efforts.

The technology package achieves this acceleration in four ways. First, by funding research and development, the program can increase the supply of energy efficiency technology available to everyone. Second, by providing reliable information on energy technologies, the program can make it cheaper for firms and individuals to identify cost-effective investments and increase the rate of penetration of new technologies into the market. Third, the program can coordinate private actions in a way that helps to reap the benefits of collective learning and group efforts, especially in new industries. Finally, the program includes measures to overcome agency problems, where the person paying the energy bill is not the same as the person making the investment decision. Let us consider these four approaches in turn.

First, scientific and technological knowledge is a public good. It is well known among economists that competitive markets tend to generate a sub-optimal amount of technological advancement, because the returns to those advancements are shared broadly, not just by those who invested in their development.[17] This is one basic rationale behind government involvement in research and development and a reason why education is one of the most important roles of government in all advanced nations. Our results simply reflect the fact that if the government bears a greater amount of responsibility for investing in research and disseminating technical information, firms and households will be able to make better investments and acquire new technologies at lower cost, thereby increasing their productivity.

Examples of the benefits of public investment in research can be seen in semi-conductors, nuclear power, and the Internet. In each of these cases, profitable opportunities for private investment became available as a result of extensive public investment in research and development.

Second, there is a substantial literature spanning 40 years that shows that all firms are not all equally efficient.[18] Instead, firms within an industry vary substantially in the efficiency with which they deploy labor, capital, and other inputs. This reflects the fact that the value of information about technology and management approaches is uncertain, and acquiring information is costly. If the cost of acquiring accurate information could be reduced, firms would move closer to the technological frontier, and the productivity of those firms and of the economy as a whole could be increased. Examples of public energy programs that reduce the cost of private decision making include the program of energy efficiency labeling requirements for appliances such as water heaters, refrigerators, and air conditioners.

Third, it is well known that new technologies often undergo rapid price reductions as the volume of production increases. This has been most visible in recent years for computers, but extensive empirical studies have shown it to be true for most complex mass-produced equipment. Emerging clean and renewable energy technologies such as fuel cells, wind turbines, photovoltaic cells, and cellulosic ethanol are all undergoing rapid cost declines as research, development, and production volumes increase. For instance, the cost of wind-generated electricity has fallen by more than a factor of five since the mid-1980s (NREL 2000), and costs are expected to continue to decline rapidly in the coming decade (Chapman et al. 1998). In 2000, more new wind capacity than new nuclear capacity was installed worldwide, and Germany replaced 1% of its entire generating capacity with new wind turbines

[Schliegelmilch 2001). The cost of combined heat and power systems, which use waste heat from industrial applications or building heating systems to produce electricity, is also declining rapidly as production experience grows (Elliott and Spurr 1999). Through programs ranging from fundamental research and demonstration projects to government purchases and coordinated programs of purchases by utilities and private industry, the policy package we model helps to accelerate the rate and reduce the cost of transition toward cleaner energy systems.

Finally, in many cases the barrier to the adoption of energy-efficient technologies is the fact that the people who make decisions regarding energy consumption are not the ones who pay the energy bills. The simplest example of this is a building tenant who does not pay a separate electricity bill. Since the landlord pays the utility bill and collects the same amount of rent regardless of how much energy the tenant uses, the tenant has no incentive to economize on energy by using more efficient equipment like compact fluorescent light bulbs or even to turn the lights off at night. Government programs like "Energy Star" and the "Green Buildings Program" help overcome these problems by promoting the use of more efficient equipment, including appliances and heating/cooling units. Our results merely reflect the fact that increased investment in programs like these will result in increased use of energy-efficient equipment. These factors, along with the price stimulus provided by the carbon tax, provide incentives for adopting cost-effective energy-efficient technologies, as our results show.

2. A POLICY PACKAGE TO IMPROVE ENERGY EFFICIENCY

The policy package examined in this report has four components:

1. a market mechanism that would lower the costs of labor without decreasing wages, and increase the costs of fossil fuels,
2. policies to promote adoption of clean energy technologies,
3. policies to preserve competitiveness of fossil fuel and energy-intensive industries, and
4. policies to ensure a just transition for workers in affected industries and residents of affected communities.

2.1. The market mechanism

The first component of the policy package is a price incentive for the reduction of greenhouse gases that consists of a tax on the carbon content of fuels,[19] with the revenue returned through a cut in labor taxes. A carbon tax places the highest burden on coal, followed by oil, then natural gas. Solar, wind, sustainably harvested biomass, and other renewable energy sources are not subject to the tax. A carbon tax is a reasonably good proxy for a general air pollution tax, although some have suggested that an even higher relative burden on coal is appropriate to capture all the air-pollution-related damages from different fuels (Norland and Ninassi 1998). An equalizing charge would be placed on electricity from nuclear and hydroelectric power.[20] There are several reasons for including the equalizing charge. The policy set is aimed at promoting the development and implementation of relatively new technologies. As both nuclear and hydroelectric power are mature, giving them the same treatment as the newer technologies is inappropriate. Equalizing charges are common components of environmental and other tax regimes. A similar equalizing charge was in the Clinton Administration's Btu tax proposal and in nearly all of the European environmental tax reforms proposed or enacted. Also, without an equalizing charge the carbon tax would produce regional inequities and severe disruption of some industries, with attendant loss of jobs. Aluminum, for example, is produced in the Pacific Northwest as well as in some Eastern states. While Northwest producers rely largely on hydroelectric power, some of their Eastern counterparts use coal-based electricity. Exempting Northwestern producers from the carbon tax would likely lead to closure of much, if not all, Eastern production disadvantaged by the absence of hydroelectric capacity.

The tax would be phased in over a five-year period. The final tax rate would be $50 per ton of carbon emitted, roughly equivalent to $0.13 on a gallon of gasoline. It would raise $70-80 billion in the early years when fully phased in.[21] The majority of the revenues from the carbon/energy tax would be returned to households through reductions in taxes on labor. Most previous macroeconomic studies that examine the effect of allowing the revenues from a carbon tax to be recycled through cuts in labor taxes have found that the effect on employment is positive, and the effect on gross domestic product is positive or near zero (Hoerner and Bosquet 2001; Repetto and Austin 1997; INFRAS and Ecoplan 1996; Majocci 1996).

In the scenario we examine, the labor tax cut would take the form of a refundable credit against income taxes for part of the payroll taxes paid by workers.[22] This would effectively exempt the first $6,044 of earnings from the payroll tax, but with no effect on Social Security collections and disbursements. This exemption would be phased out for earnings above $65,000. Estimates by the Institute on Taxation and Economic Policy show that the proposal is mildly progressive over the entire income range. While most of the revenues from the carbon tax are used to reduce payroll taxes as described above, a portion of the revenue – rising over time from 29% to about 49% – is used to fund the energy efficiency and just-transition programs described below. As a large energy consumer, the federal government would save a substantial amount of money under this policy package, about $2 billion in 2010 and just under $3 billion in 2020. If these funds were used to offset administrative costs of the efficiency programs, the share of tax revenues needed would fall by 3.0 percentage points in 2010 and 5.6 points in 2020.

2.2. Policies to promote clean energy technologies

The second component of the package is a set of policies to promote research, development, and commercialization of existing energy efficiency and clean energy technologies. These policies complement the market mechanism by developing more efficient and less expensive ways of reducing fossil fuel consumption and by helping businesses and consumers identify and adopt them. The economic literature is virtually unanimous in concluding that the costs of achieving energy efficiency improvements or energy-related emissions reductions are substantially reduced, and may even be negative, if measures to stimulate the more rapid development and adoption of new technologies are included in the policy package.[23]

By their nature, energy efficiency promotion policies are diverse and sector specific. In order to identify a credible package of technology initiatives, we adopted (with some modifications)[24] the technology policy package from *Scenarios for a Clean Energy Future* (Interlaboratory Working Group 2000; henceforth the "CEF report").[25] The CEF report is the product of a massive multi-year effort by the national laboratories of the U.S. Department of Energy to develop a consensus national energy strategy based on sound science and consistent economic assumptions. It is the first time the national laboratories have put forward such a strategy together with a package of concrete implementation policies. It is the most comprehensive, thoroughly documented, reviewed, and carefully modeled effort of its type.

The CEF report includes more then 50 individual policies to promote energy efficiency and renewable energy. Some policies cut across sectors, such as the recommended increase in federal energy-related

TABLE 1
Major policies in the CEF advanced scenario*

Buildings	• Efficiency standards for equipment • Labeling and deployment programs
Industry	• Voluntary programs • Agreements with individual industries and trade associations
Transportation	• Tax incentives for super-efficient vehicles • Increased CAFE standards • "Pay-at-the-pump" auto insurance
Electric generation	• Renewable energy portfolio standards and production tax credits • Electric industry marginal cost pricing**
Cross-sector policies	• Doubled federal research and development • Domestic carbon market mechanism (auctioned permit or tax, $50/ton of carbon)

* The scenarios are defined by approximately 50 policies; the 11 listed here are the most important ones in the advanced scenario. Each policy is specified in terms of magnitude and timing. For instance, "efficiency standards for equipment" comprises 16 new equipment standards introduced in various years with specific levels of minimum efficiencies. For details, see the CEF report.

** Note that the CEF assumes that marginal cost pricing will be implemented through electric utility industry restructuring. We do not make this assumption, as the same policies could also be implemented through regulatory reforms.

Source: CEF report (Interlaboratory Working Group 2000).

research and development, but most are sector specific. The policy package is based on CEF's "advanced scenario," including the corporate average fuel economy (CAFE) "sensitivity case."[26] A brief summary of the policy package is provided in **Table 1**. A more detailed description for each of the major sectors – residential and commercial buildings, industry, transportation, and electric utilities – is contained in Appendix B. Appendix B also makes clear where we deviate from the CEF policies. (Some of these deviations are significant, e.g., we model considerably higher requirements for electric generation from non-hydroelectric renewables such as wind, solar, geothermal, and biomass.)

In recent experience, a wide range of firms have been able to save millions of dollars by implementing many of the same technologies examined in the CEF report. For example, between 1993 and 1997, DuPont's chemical-processing Chamber Works facility in New Jersey implemented a number of the types of technologies highlighted in the CEF report, such as more efficient light bulbs and lighting systems; improved steam systems; combined heat and power generation; more efficient heating, ventilation, and air conditioning (HVAC) systems; and variable-speed drives for motors and optimized motor size. As a result, energy use per pound of output fell by about one third, and annual energy bills fell by $17 million, even while production increased by 9%.[27] Technologies like the ones examined in the CEF report often require a large initial investment but yield substantial energy savings over the long run. These positive, and often large, returns on investment can allow firms to increase their output and/or profitability.

Specific examples of the types of technologies included in the CEF policies include increased efficiency standards for home and commercial equipment like washing machines and air conditioning units. The transportation sector includes increases in fuel efficiency standards for cars, trucks, and sport utility vehicles as well as tax incentives for the production of highly fuel-efficient autos. In many cases, the policies outlined in CEF are not aimed at promoting specific technologies but are rather expansions of whole-system initiatives. The steam and motor challenge programs, for example, aim to help industrial facilities improve their efficiency through implementation of technology and optimized equipment as well as increased monitoring and training for personnel. Programs like these are not tied to a single specific technology or piece of equipment or type of technology, but encompass a broader range of issues, covering human as well as physical capital.

2.3. Policies to preserve competitiveness

The package examined here includes several elements to level the playing field in order to assure that U.S. firms do not lose undue market share to industries in other parts of the world that do not have to pay U.S. energy taxes or achieve U.S. emissions reductions. For industries that are not energy intensive, the labor tax cut is generally sufficient to offset the burden of the carbon-energy charge (see, e.g., Hoerner 2000). In addition, as discussed below, energy efficiency improvements induced by the plan are sufficient to offset the burden of the charge on even the most energy-intensive industries in the long run. However, this leaves two problems: maintaining the international competitiveness of U.S. fossil fuel industries themselves, and preserving the competitiveness of energy-intensive industries in the short run.[28]

To deal with these two problems, the policy package includes a border tax adjustment on carbon/energy tax payments. Such an adjustment would mean that importers of fossil fuels and energy-intensive bulk materials are required to pay whatever taxes or emissions-permit fees would have been required had the products been produced in the U.S. In addition, taxes associated with U.S. production of energy-intensive exports would be rebated to the producer. Such border adjustments are currently used for U.S. taxes on gasoline, alcoholic beverages, ozone-depleting chemicals, and many other goods, and on value-added taxes (VATs) (which are not used in the U.S. but are common in Europe). Border adjustments are considered a normal part of the tax system and are explicitly allowed under the General Agreement on Tariffs and Trade (GATT) and World Trade Organization (WTO) regulations (see, e.g., Demeret and Stewardson 1994 and Hoerner and Muller 1996).

Border tax adjustments can be complicated to administer. We would therefore limit the border adjustment to products for which the carbon/energy tax has a significant impact on price (set at 2% for the purposes of this study). This includes fossil fuels themselves, electricity, and a handful of energy-intensive bulk materials, such as primary metals, cement, primary paper, and certain chemicals.

2.4. Policies for a just transition

As noted above, prior research suggests that a moderate carbon tax used to offset part of the payroll tax in conjunction with policies aimed at increasing energy efficiency generally have small effects on overall GDP and employment. Nevertheless, in some industries, most notably coal mining, some job loss appears unavoidable under any effective energy efficiency or carbon abatement policy. The policy package modeled here includes policies designed to provide these workers with a just transition to new skills or a bridge to retirement. These policies are intended to provide economic compensation for any workers who lose their jobs as a result of the policies modeled here.

We modeled two alternative packages. The reference package is based on the services that would be required to return laid-off workers to employment at substantially similar wage rates with no loss of income during the transition. It would include two years of full, unconditional income replacement, up to four years of full-time training or educational benefits, and living stipends for an additional two years for those who remain in training. It includes replacement of health insurance and contributions to retirement plans. The value of the package is set at 150% of the estimated average loss to provide additional protection to workers who take longer to find new jobs and compensation for other losses (e.g., moving expenses, tool purchases, etc.). Workers within five years of retirement would have the option of forgoing training and receiving additional income replacement as a bridge to retirement. The average cost of this program is approximately $122,000 per worker.[29] For workers in the coal mining sector, whose salaries average just over $62,000 per year, the average cost of the benefit package would equal about $196,000.[30]

The alternative package would simply make a cash payment to eligible workers equal to their after-tax wages at layoff for up to five years. If a worker finds a new job within five years, for every dollar earned the payment would be reduced by 50 cents. The cost of this benefit package is slightly more than that of the first package.

These benefits would be available to workers employed in affected industries prior to the adoption of the policies who are subsequently laid off. The training programs would be administered by councils composed of representatives of local governments and workers from affected industries. For unionized industries, the worker representatives would be appointed by the union. Experience has shown that participation by workers in the design of training programs is essential to ensure that the programs provide the kind of training that workers need if they are to find new employment of comparable quality.

Workers are often skeptical of transition programs and their ability to either compensate laid-off workers or help them find suitable employment. Much of this suspicion arises as a consequence of past experience with such programs as the Job Training Partnership Act (JTPA) and the Trade Adjustment Assistance program (TAA), which have had mediocre results at best. Assessments of both programs have found that only about 40% of participants found jobs related to the training they received, and most of those jobs offered greatly reduced wages. One major cause of this problem has been the low levels of funding provided to these programs. In 1996, for example, the JTPA Title III program (designed for laid-off workers) allocated only about $4,000 for each participant. For workers dislocated by international competition, TAA benefits are meant to be an entitlement, but the program's appropriations often ran out well short of the end of the program year, leaving entitled workers with no benefits.[31] For these reasons, the package modeled here includes transitional assistance as a fully funded and integral piece of the policy approach.

Two aspects of the transition package are worth further discussion here. The first is that the package is modeled with the assumption that little new hiring will occur in heavily affected sectors; layoffs are calculated as reductions in labor force less attrition. The second is that industries would be pre-certified so that affected workers would be immediately eligible for the program, thus avoiding many of the administrative problems that have plagued transition programs in the past.

Large-scale layoffs can affect not only the individual worker but also the communities in which they live, particularly communities with high concentrations of layoffs. In such areas, merely retraining displaced workers is likely to be insufficient to guarantee re-employment and to help ensure the economic health of the community. In order to assist local communities, the policy package provides funds from the carbon/energy tax revenues, equal to $10,000 per job lost, for investment in local community development.[32] The purpose of providing community development funds is to help generate employment opportu-nities in affected communities, both to provide local opportunities for workers who have lost jobs in energy-intensive industries and also to maintain the economic base of the communities that rely on such jobs. Community development funds can also help attract new employers to regions suffering losses.

3. THE MODELING APPROACH

The economic impacts of the policy package described above were modeled using LIFT (Long-term Interindustry Forecasting Tool), a 97-sector inter-industry macroeconomic model created by the Inforum modeling group. Inforum, an academic research and consulting group based at the University of Maryland, has a well-respected, 20-year track record performing macroeconomic modeling.

The LIFT model tracks more than 800 macroeconomic variables, and is unique in the extent to which it builds up aggregate demand from individual industry demands at a high level of industrial detail. The consumption side of the model has 92 demand categories, arranged in functional groups that allow substitution and complementarity effects to be explicitly estimated. Equipment investment for each industry is estimated using a two-stage, three-equation system that simultaneously determines investment, labor, and energy demand. Industry wage trends are determined primarily by industry-specific labor productivity equations. The model also has a rich array of tax and fiscal policy handles and a highly detailed government sector. For this project, an additional module was added to the model to perform carbon and energy accounting by industry, sector, and fuel.

A more detailed overview of the LIFT model can be found in the published literature,[33] and many aspects of the model are explained in Inforum working papers.[34]

For this effort, the model baseline was first calibrated to the GDP growth rates and energy efficiency improvements contained in the 2001 *Annual Energy Outlook* of the U.S. Energy Information Administration. GDP was calibrated primarily by exogenous adjustment in the rate of labor productivity improvement. Energy efficiency was calibrated on the production side by adjusting the technical coefficients of the factor demand matrix and on the consumption side by calibrating the consumer demand system.

The following energy policies were then added to the model:

- the carbon/energy tax increases and labor tax reduction described above;
- the energy efficiency improvements from the CEF report and the additional energy efficiency policies described in Appendix B were implemented using a ratio approach;[35]
- private investment and government spending sufficient to achieve these energy efficiencies were added to the current investment and spending levels;[36]
- compensation for lost jobs and community transition assistance were implemented as an increase in unemployment insurance expenditures and general state spending, respectively; and
- border adjustments were applied to each industry with a carbon/energy tax burden of 2% or more of the total cost of production.

We calculated the number of workers eligible for transitional assistance in two ways, with results reported below under both approaches. (Although the two approaches resulted in somewhat different shares of the carbon/energy tax revenues going to transition assistance, the macroeconomic results did not differ appreciably depending on the approach used and so are not reported separately.) Under the first approach, we identify the LIFT sectors likely to face policy-induced job loss as those whose aggregate carbon tax payments are at least 2% of gross output in at least one year. We then estimate the number of eligible workers in any given year as the decline in sectoral employment from the previous year, less voluntary attrition through retirement and the like (set at 3% annually).[37] Because it is based on the net year-to-year changes in sectoral employment, this method should elicit an estimate close to the number of policy-induced layoffs. However, it cannot identify job losses that are offset by new hires because these offsetting positions will not appear as a net reduction in employment; thus, this method will understate slightly the number of eligible workers.

The second approach to eligibility attempts to identify gross layoffs in the energy-intensive industries and does not attempt to distinguish between policy-induced losses and those that would have occurred without the policy package. We estimated the layoff levels based on historic average rates by industry and on the historic level of responsiveness of layoff rates to changes in worker productivity and industrial output levels. All such layoffs in the fossil fuel sectors are eligible for the transition program. Layoffs in energy-intensive industries (defined as industries at the four-digit SIC level for which the carbon/energy tax is 2% or more of gross output) are eligible after the first three years. (We estimate that policy-induced layoffs in non-fuel energy-intensive industries are negligible – less than 1,000 jobs nationwide – in the first three years.) In both cases, eligibility is restricted to those employed in the relevant industry at the time the policy package is adopted. In both cases, the program expenditures are modeled as increases in unemployment insurance payments.

As between these two approaches to eligibility, we believe the first approach provides a more accurate estimate of the actual number of persons laid off as a result of the policy package. However, to administer the first approach it would be necessary to determine whether the layoffs at a particular plant were caused by the climate policy or unrelated factors. The history of transition assistance programs suggests that these determinations are often difficult and lengthy, and have frequently prevented assistance from reaching workers in a timely fashion (Barrett 2001a). The second approach treats all laid-off workers as eligible for the program, including those not laid off due to the climate policies. The second approach is more administrable because it allows immediate certification of workers based on objectively observable criteria (i.e., employment in one of a set of pre-determined industries). However, it is worth observing that, if a method of rapidly and accurately determining the cause of particular layoff events could be developed, the cost of the transition program could be considerably reduced, the benefits could be substantially increased, or both.

See the discussion on energy prices and expenditures in the following section for estimates of workers receiving transition assistance under the two approaches. In order to avoid underestimating the necessary cost of the transition program, we present our results based on the second method.

In a few cases more specific adjustments had to be made in the model, such as to capture the increased cost and labor requirements to produce more fuel-efficient vehicles and changes in the technical requirements of several industries to account for recycling efficiencies.

3.1. Strengths and limitations

Estimates of the cost of achieving carbon emissions reductions in the U.S. vary widely. For example, estimates of the impact on GDP of reducing carbon dioxide emissions to the Kyoto level are mainly in the range of a 1% gain to a 2% loss (IPPC 1996). A number of factors influence the forecast of economic outcome, including baseline, model type, the policy package modeled, and whether the economic value of the environmental benefit is included in the study (Weyant 2000; Repetto and Austin 1997). However, two factors stand out as particularly critical.

The first factor is whether the revenues from a carbon tax or permit system are used to cut other taxes. The economic literature, both theoretical[38] and empirical,[39] is unanimous in concluding that, when the revenues from a carbon charge are used to cut other distorting taxes, the impact of the combined package (carbon charge and tax cut) on GDP is much more positive (or less negative) than for a carbon charge alone. This outcome can occur because the tax cut typically has a positive impact on the economy that offsets at least some of the negative impact of the carbon charge. Depending on the choice of tax cut, economic conditions, model assumptions, and other factors, the net effect of the combined package on GDP may be positive, negative, or zero, but in any case is typically small relative to a policy that relies either on a carbon tax or a grandfathered permit system[40] alone.

The second factor is the treatment of technological change and whether the policy package includes technology policies or relies exclusively on a carbon tax to achieve emissions reductions. Studies that do not explicitly consider technology-based policies tend to find much higher costs of emission reductions than those that do. Broadly speaking, there are two approaches to modeling reductions in fossil fuel use, usually referred to as "top-down" and "bottom-up," each with its own strengths and weaknesses. Top-down studies usually use computable general equilibrium (CGE) models or macroeconometric models to estimate the effects of a carbon/energy reduction policy. These models either assume that firms and individuals optimize their decisions given prices, preferences, and technological constraints (CGE models), or assume that historical relationships between macroeconomic aggregates will continue to hold (macroeconometric models). However, both types of models generally incorporate very simple and unrealistic models of technological change and improvement – usually little more than time trends (Wilson and Swisher 1993; Weyant 2000). The rate at which energy-efficiency technology improves does not vary in response to changes in any policy variable in any of the major multi-sectoral economic models that have been used for economic forecasts of climate policy.

Bottom-up approaches, on the other hand, model individual technology decisions at the level of specific industries and product choices. This approach will normally involve studying known technologies in varying phases of research, development, and commercialization. Such studies can capture the effects of technological change and the potential of emerging technologies, but they often fail to capture the adjustment costs that prevent the economy from moving instantly to adopt these options. This was particularly true of older studies that rarely incorporated features such as market penetration models to account for capital replacement rates. In addition, these studies often focus on the benefits to particular industries or sectors, without estimating the impact on GDP or other macroeconomic variables.

According to a comprehensive literature review undertaken in 1995, bottom-up studies typically find that, over a one- to two-decade time span, reductions in carbon emissions on the order of 20-30% can be achieved at a net saving or for approximately zero net cost, with larger savings possible over longer time horizons (IPPC 1996). More recent engineering studies of the U.S. economy have generally continued to support this conclusion.[41] Under a broad range of modeling approaches and assumptions, studies are virtually unanimous in concluding that the costs of energy efficiency improvements or greenhouse gas reductions are reduced, and in some cases switch to a net benefit, if new technologies are introduced more rapidly (Edmonds, Roop, and Scott 2000).

Our approach in this study is to take the technology forecast from a state-of-the-art bottom-up study,[42] and then use a macroeconometric model to explore the implications of this technology forecast, a carbon charge, and a labor tax cut on the macroeconomic and sector-specific levels. This approach allows us to take advantage of the comprehensive nature of the macroeconometric model without restricting ourselves to its oversimplified technology assumptions. Our results are generally similar to those of previous efforts to link economic models to technology forecasting models,[43] in that they show a modest improvement in GDP for a moderate energy and carbon efficiency policy.

This approach has certain advantages, but also certain limitations. First, because we are relying on an integrated technology forecast, it is difficult to untangle the effects of particular policies from the impacts of the package as a whole. For example, we are unable to estimate the impact of implementing the technology policies without the carbon tax.

Our reliance on the CEF as the primary source of technological cost and penetration forecasts also limits the range of technical approaches we can explore. For example, the CEF report contains no analysis of the potential contribution of mass transit as a means to reduce carbon emissions and fossil fuel consumption. Increased investment in mass transit could provide substantial benefits in reducing emissions of carbon as well as other pollutants and could be useful in helping low-income families avoid some of the burden of increased gasoline prices that they might otherwise bear. A truly comprehensive policy package should examine the potential role of this important option. Because we lack compatible capital cost and energy savings data for transit investment, we were unable to include it in the policy package. We hope to examine this and other policies in future work.

In addition, it is important to note that the CEF policies are not universally accepted. The CAFE standards we model, for example, are higher than those currently supported by the auto industry and auto workers. Finally, CEF does not include technologies such as carbon sequestration options and "clean coal technologies" designed to make coal-fired electricity less environmentally harmful. Whether or not these options will be viable alternatives for reducing carbon and other emissions remains to be seen, but, in any case, the current costs of geological sequestration are well above the $50 per ton carbon tax we model, and technological questions remain about the feasibility and environmental impact of storing large amounts of carbon for long periods.

The second limitation to our approach derives from the limits of our overall framework, the LIFT model. LIFT is a macroeconometric model with a good forecasting track record. However, it is not forward looking in a rational expectations sense; instead, it reacts to policies as they are adopted. We have attempted to overcome this limitation by using a gradual phase-in of the market mechanism and an engineering approach to technology forecasting that is inherently forward looking, but these measures offer at best a partial solution. Macroeconomic models also assume that historically observed relationships between macroeconomic aggregates will continue to hold. Phenomena such as increased globalization have been in play over decades, and so we expect the model to capture them to some extent. But when cumulative quantitative changes result in fundamental changes in the economic regime, no historically based model can guarantee accurate forecasts. It is also impossible to fully account for random factors such as Mideast unrest or year-to-year weather variations except by scenario analysis.

Third, although the LIFT model uses a finer degree of sectoral disaggregation than many other models, there is still substantial variation in energy intensity within the LIFT sectors, and we may fail to capture effects that are specific to narrower energy-intensive sectors (but see Hoerner and Mutl 2001 for an effort to estimate such effects using a 498-sector input-output model). The model also assumes the accuracy of the U.S. Bureau of Economic Analysis input-output estimates for inter-industry purchases of materials and services. We have commissioned further studies to assess the impacts of this policy set on selected industries, including coal and rail, that do not rely on LIFT sectorization and should thus provide a more accurate picture of the impact on freight rail.

An example of the institutional constraints of macroeconometric models arises in the case of the auto industry in relation to the CAFE standards. An increase in CAFE standards is forecast to induce an increase in the labor required to produce a car. In recent years, however, U.S. automakers have been shifting an increasing proportion of their production process to Mexico and other foreign countries, importing auto parts for assembly at domestic plants. Increases in CAFE standards that require that production processes be changed significantly may accelerate automakers' decisions to take advantage of lower labor costs and build new plants abroad rather than build new plants or retool existing ones domestically. This outcome could offset some or all of the increased demand for labor resulting from the increased labor intensity. Alternatively, the production processes that are most likely to be shipped abroad are the ones that are best understood and widely copied – and these are likely to be the ones that have been implemented domestically first. If this is the case, then fundamental changes in the automaking process may increase the need to maintain production domestically until the new technologies are well understood.[44] These types of considerations are beyond the capability of macroeconometric models, including LIFT, to analyze.[45]

Finally, technological change is, by its nature, inherently difficult to predict, and it is unrealistic to believe that information exists to identify in advance the best possible energy system for the long term. Therefore, an essential component of any plan is ongoing evaluation so that one can expand the most successful programs, refine others, and cut losses on the unsuccessful ones.

The next section describes the economic impact of the policy package implemented as described above relative to a "base case" scenario.

4. MODELING RESULTS

The economic impact of this set of policies on gross domestic product, employment and unemployment, wages, specific sectors, trade, energy security, carbon emissions, and inflation is mainly small but positive overall. The environmental benefits, though, are quite substantial. Notable exceptions to the finding of a small overall impact include large reductions in oil imports and serious employment declines in certain sectors. **Table 2** summarizes the results.

4.1. Impact on gross domestic product

As shown in **Figures 1A** and **1B**, the policy package results in a small net increase in gross domestic product. GDP increases by 0.2% in 2010 and by 0.6% in 2020, representing $31 billion in 2010 (in 1997 dollars) and $100 billion in 2020. While relatively small, the increase is not insignificant, equaling the gross state product of, say, Montana, Vermont, Wyoming, or South Dakota in 2010, or of Alaska in 2020. GDP increases on aggregate because, under the package of policies modeled here, the gross annualized investment and program cost necessary to achieve the energy saving is less than the annual value of energy saved. As a result of this reduction in materials costs, both productivity and GDP increase slightly.

TABLE 2
Impact of the policy package for GDP, emissions, and employment

		Baseline		Policy scenario		Percent change from baseline	
	2000	2010	2020	2010	2020	2010	2020
GDP	9,545	12,863	16,771	12,896	16,878	0.26%	0.64%
Carbon emissions	1,538	1,814	2,054	1,325	1,018	-26.99	-50.40
Total employment	141,343	154,263	164,119	154,917	165,547	0.42	0.87
Manufacturing industries	19,798	19,082	18,210	19,131	18,459	0.26	1.37
Coal mining	88	53	46	24	12	-54.14	-73.91
Ferrous metals	426	425	354	425	354	-0.08	0.00
Service industries	103,849	115,026	123,539	115,644	124,835	0.54	1.05

Note: GDP figures are in billions of 1997 dollars, carbon emissions are in millions of metric tons, and employment figures are in thousands of jobs.

4.2. Aggregate employment and the unemployment rate

The impact of the clean energy policy package on employment is significantly positive. As shown in **Figure 2**, net job gains rise to about 660,000 jobs in 2010 and then continue to increase to around 1.4 million jobs in 2020.

The increase in jobs is primarily due to higher GDP. Other contributing factors include a slight shift in the pattern of growth toward labor-intensive sectors relative to the baseline.

The increase in employment also results in a modest decline in the unemployment rate, as shown in **Figure 3** and **Table 3**. The time pattern of these effects is similar to the employment effects, in that the unemployment rate falls fairly steadily throughout the forecast period, declining by four-tenths of a percentage point in 2010 and by eight-tenths of a percentage point in 2020.

4.3. Carbon emissions

The policy package modeled here provides substantial benefits in enhancing both carbon and energy efficiency. The package also has some impacts on emissions of methane, which is a more powerful greenhouse gas than carbon dioxide, though produced in much lower quantities. (Appendix B discusses the impacts of this policy package on methane emissions.) Carbon emissions are a reasonable proxy for the combined sum of air pollution from burning fossil fuels, in the sense that most carbon reduction policies, including this one, will reduce most other air pollutants by at least a proportional amount, all else being equal.[46]

As shown in **Figure 4**, under the policy package carbon emissions decline dramatically relative to the baseline. **Tables 4** and **5** show carbon emissions under the baseline and policy scenarios by sector and by fuel. While all sectors make substantial progress in reducing carbon emissions, the largest percentage reductions come from the commercial sector, due in large part to the fact that much of commercial sector emissions come from electricity use in buildings. The policy package modeled here includes substantial increases in the energy efficiency of buildings as well as advances in carbon efficiency of electricity generation, resulting in the large reductions seen in the commercial and, to a lesser extent, household sectors.

FIGURE 1A

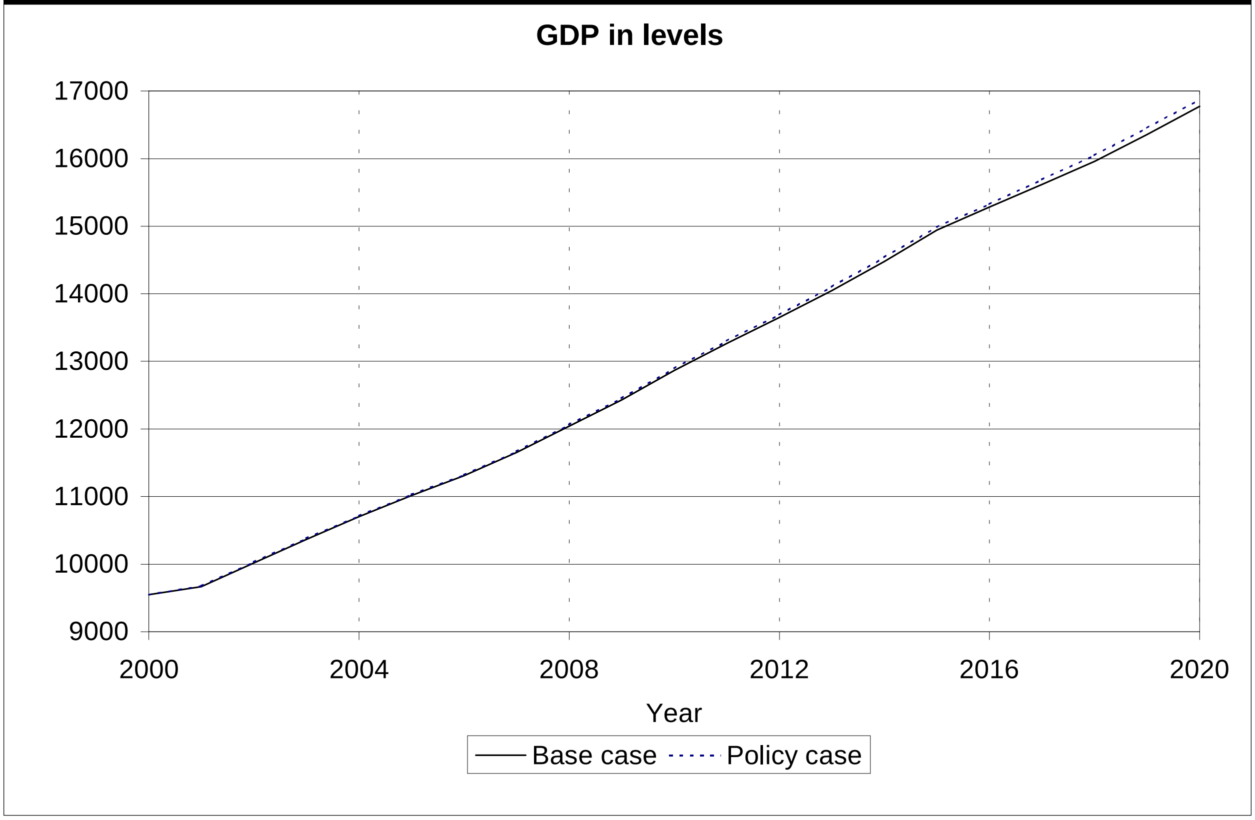


FIGURE 1B

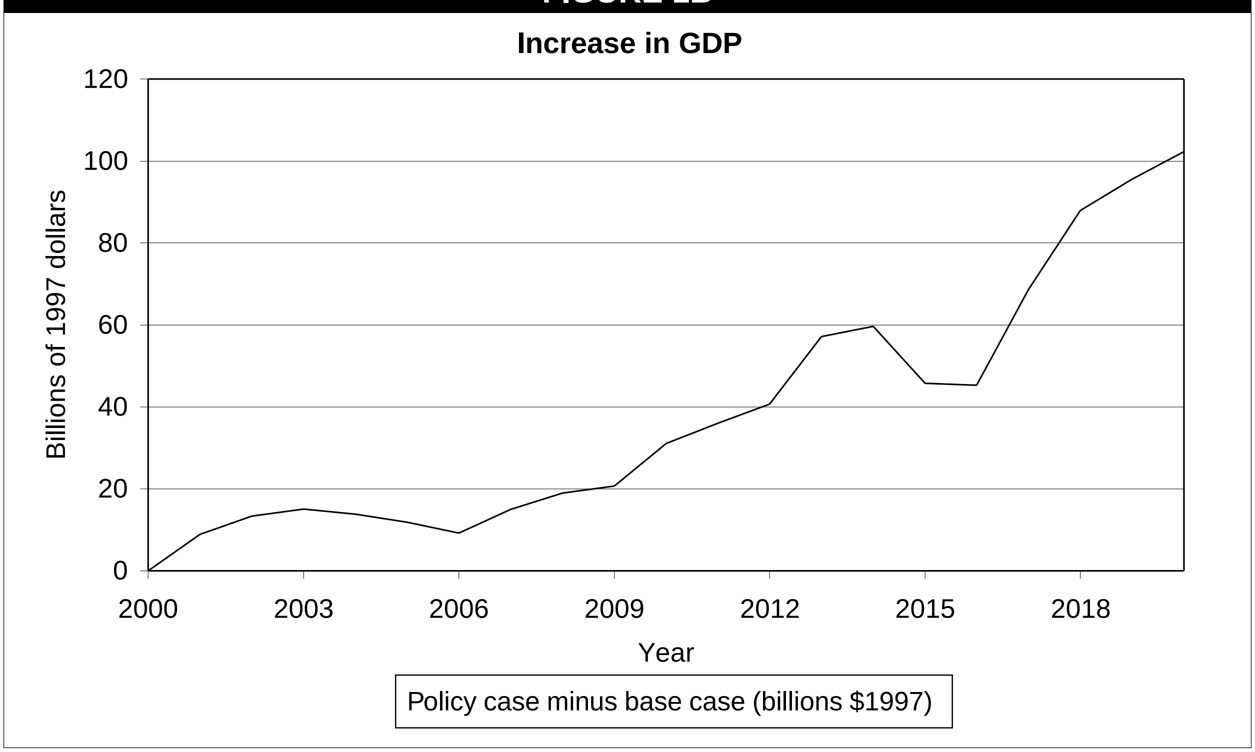


FIGURE 2

Total employment

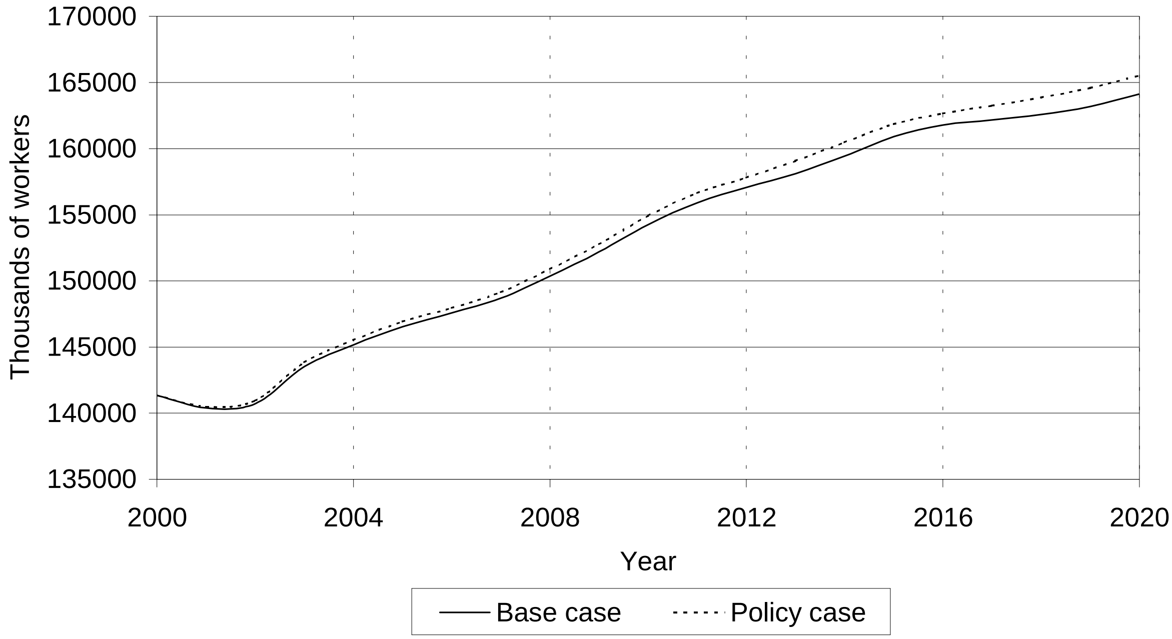


FIGURE 3

Change in umemployment rate (policy case minus base case)

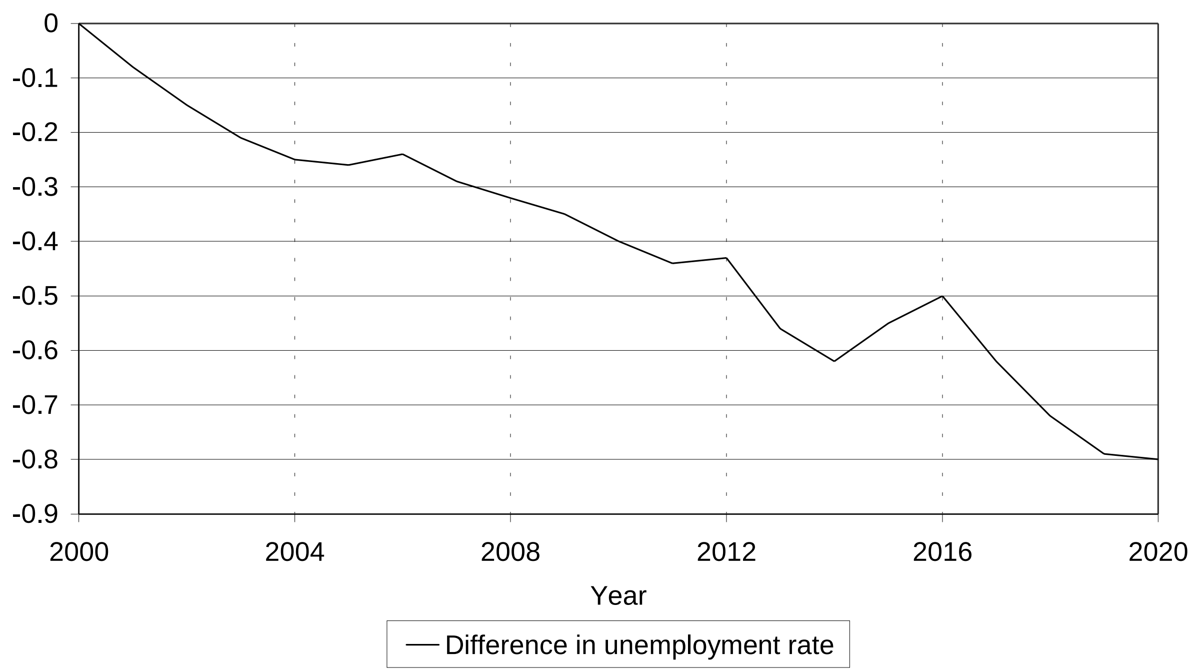


TABLE 3
Projected unemployment rate

	2000	2004	2008	2012	2016	2020
Baseline	4.0	5.2	5.8	5.2	4.9	5.6
Policy scenario	4.0	4.9	5.5	4.8	4.4	4.8
Difference (policy - baseline)	0.0	-0.3	-0.3	-0.4	-0.5	-0.8

FIGURE 4

Carbon emissions

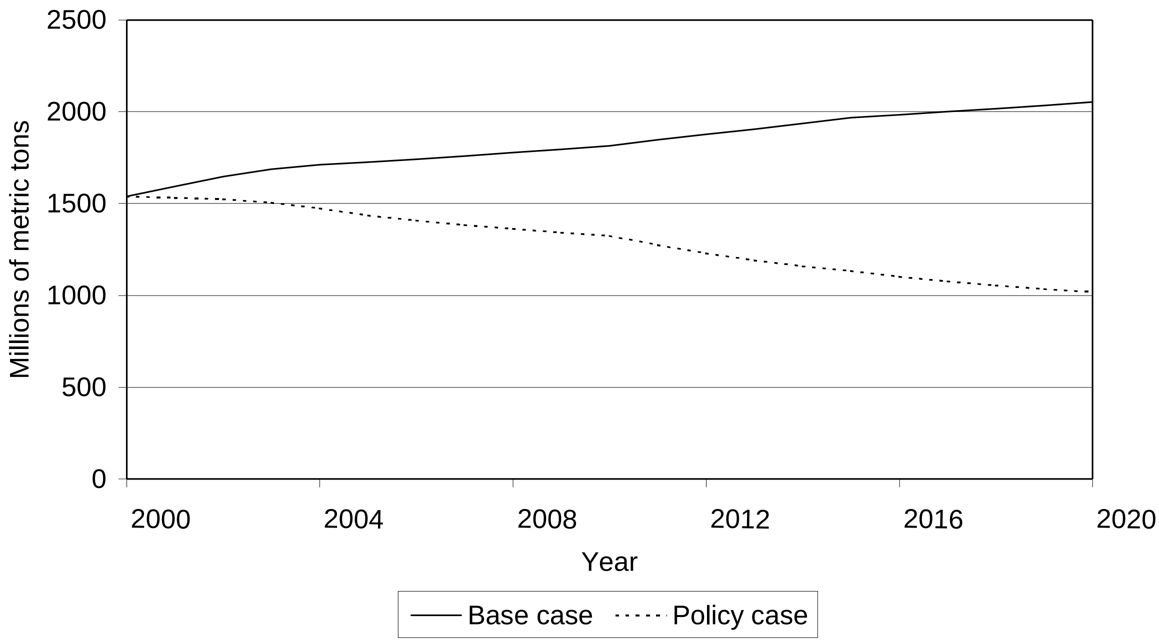


TABLE 4
Carbon emissions by sector

		Baseline		Policy scenario	
	1999	2010	2020	2010	2020
Manufacturing	480	530	587	379	310
Transportation	498	635	741	547	497
Commercial	243	308	341	179	83
Households	289	341	385	219	128
Total	1,511	1,814	2,054	1,325	1,018

TABLE 5
Carbon emissions by fuel

		Baseline		Policy scenario	
	1999	2010	2020	2010	2020
Coal	549	636	672	320	72
Petroleum	650	759	862	653	589
Natural gas	312	413	514	350	366
Total	1,511	1,814	2,054	1,324	1,018

Of all the fossil fuels, coal use declines the most in this model. One reason for this decline is the relatively high carbon content of coal-fired electricity. With existing coal-steam generators averaging between 30% and 35% thermal efficiency, compared to the near-50% efficiency of new combined-cycle natural gas plants, gas-fired electricity has an advantage in a carbon- or pollution-constrained environment. Moreover, natural gas is less carbon intensive than coal per BTU.

4.4. Wage effects

The policy package would result in increases in real hourly wages after payroll taxes in every year relative to the baseline. The average real hourly wage will be 1.3% higher in 2010. After peaking in 2005, the increase in after-tax wages declines steadily to 2020, although wages are still more than 0.3% higher in that year relative to the base case. This increase in wages is caused by several interacting effects. First, there is a cut in taxes on wages, most of which benefits workers. Although this wage increase is partly offset by higher energy prices, improvements in energy efficiency help to mitigate that offset. Second, there is a small but detectable shift in the pattern of growth from capital- and energy-intensive industries toward labor- and skill-intensive industries, resulting in a slight increase in labor demand.

The diminishing increase in wages after 2005, illustrated in **Figure 5**, is the result of two factors. First, reductions in aggregate carbon emissions cause a steady decline in carbon tax revenues after the tax is fully phased in in 2005. This results in a smaller labor tax cut. Second, a larger share of the tax revenues are devoted to transitional assistance for workers and communities in the later years, further reducing the labor tax cut.

4.5. Energy security

As **Figure 6** shows, crude oil imports fall considerably under this policy package. Relative to the baseline, imports decline by 610 million barrels per year in 2010, with the decline increasing to 1.54 billion barrels per year by 2020. This reduction is slightly more than all the oil imported from OPEC in 1999. Over the course of 20 years, these savings would represent more than six times the estimated recoverable oil underlying the Arctic National Wildlife Refuge (ANWR) in Alaska.[47]

Under this policy, U.S. dependence on foreign oil declines dramatically relative to the baseline, as does U.S. dependence on oil overall. Under the business-as-usual scenario, oil consumption (crude and net imports of refined products) as a share of GDP falls gradually to about 80% of its 2000 level by 2020.

FIGURE 5

Employee compensation (after payroll taxes)

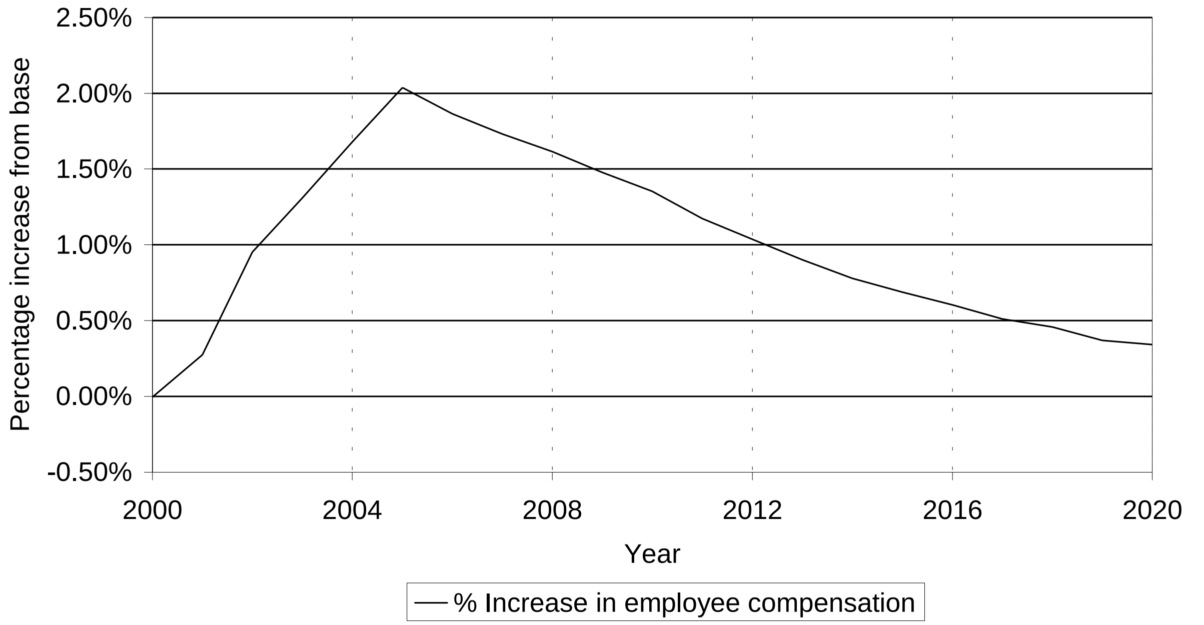


FIGURE 6

Annual crude oil imports

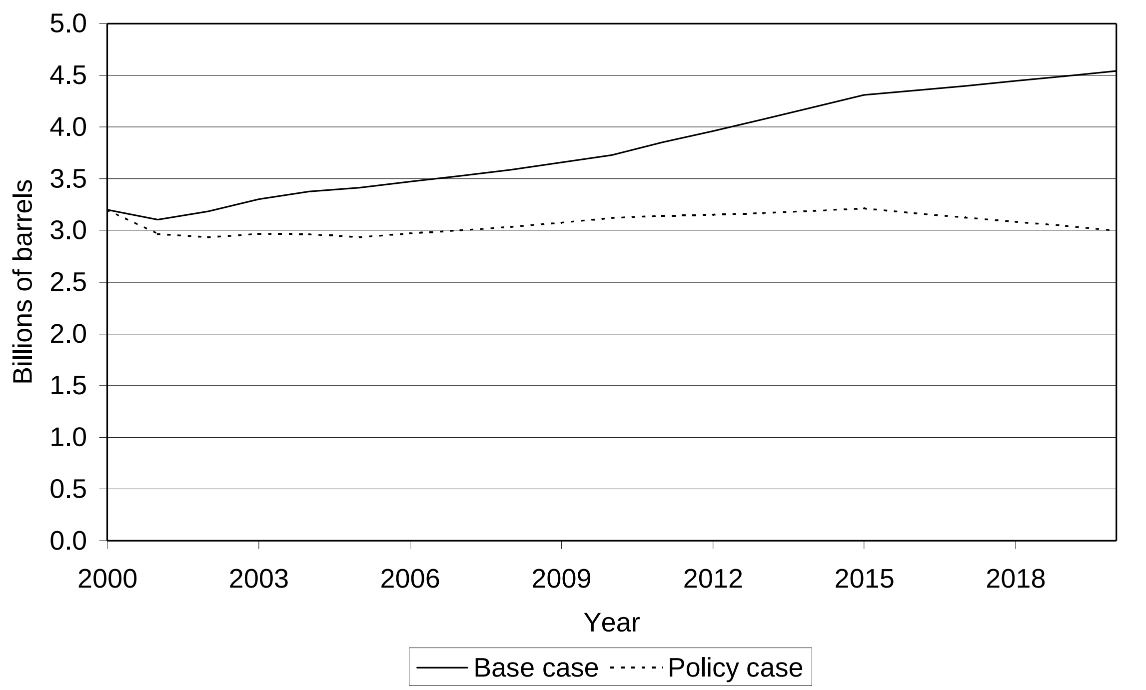
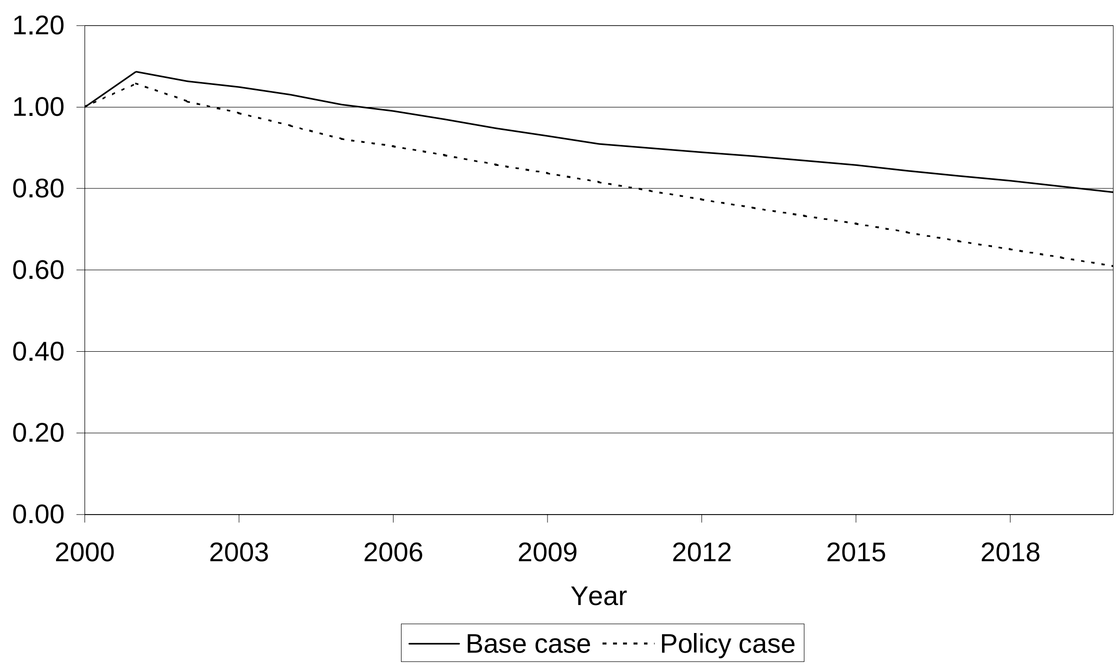


FIGURE 7

Oil consumption as a share of GDP (index)



Under the policy package, this gradual decline is substantially accelerated: by 2020, consumption as a share of GDP has fallen to 60% of its current level (**Figure 7**), substantially lowering U.S. vulnerability to price shocks on international energy markets.

With oil imports and consumption declining so substantially, even quite large increases in global oil prices would be unlikely to have much macroeconomic impact on inflation or growth. The U.S. would be virtually immunized from recessions induced by oil price shocks.

4.6. Inflation

The effect of this policy package on inflation is very small – less than two hundredths of a percentage point in 16 of the 20 years in the forecast. However, the effect of the policy package is to increase inflation slightly in the early years, as the carbon/energy tax is phased in, and reduce inflation in every year after 2006. This is in keeping with the general pattern of economic consequences, as increases in productivity tend to moderate inflation, all else held constant.

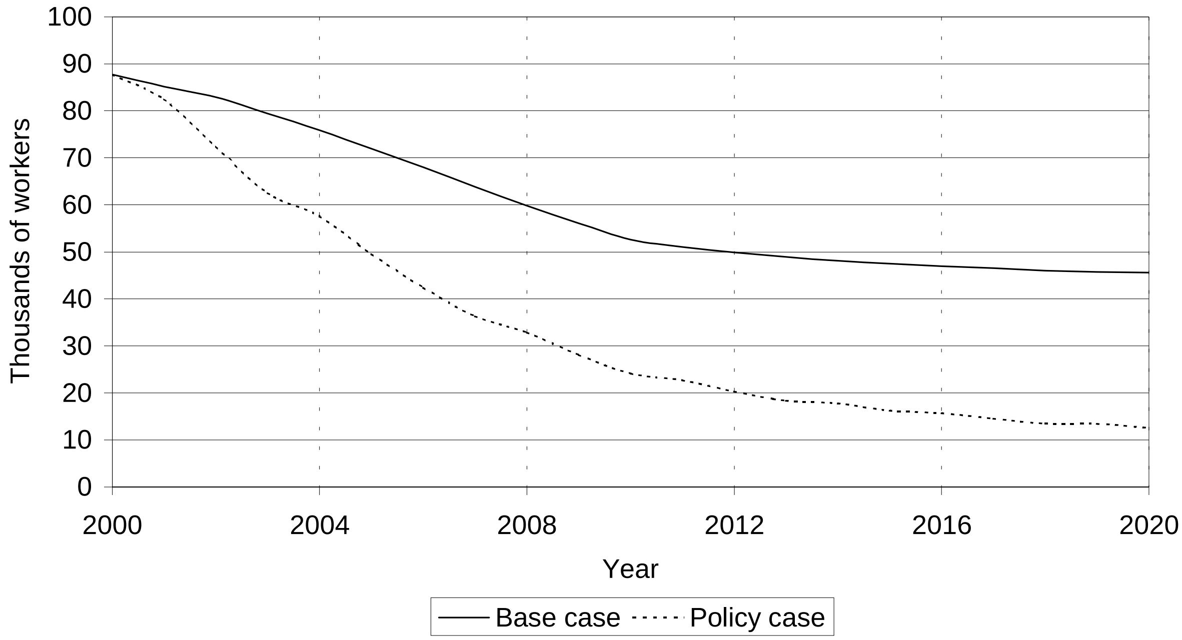
4.7. Sectoral impacts

While there are too many sectors in the model to examine each one individually, there are a few cases that deserve special attention. (Table C1 in Appendix C summarizes projected changes in employment relative to the baseline for all industries, and Table C2 provides estimates of policy-related layoffs in energy-intensive industries.)

In terms of percentage change in employment, the coal industry is most negatively affected by the

FIGURE 8

Coal employment



policy package. While the coal mining sector already faces reduced employment levels in the baseline (**Figure 8)**, the addition of the policy package accelerates this trend considerably, so that by 2020 employment is little more than a quarter of what it would have otherwise been. (Note that reductions in employment levels or number of employment-years should not be confused with layoffs. Layoffs are equal to reductions in the labor force, minus retirement and voluntary turnover, plus any new hires that occur despite the overall shrinkage. For a more extensive discussion, see Appendix C.)

This accelerated decline hits coal because coal is the most carbon intensive of the fossil fuels, and, as the demand for energy falls relative to the baseline as a result of the carbon tax and energy efficiency improvements, demand for coal-based energy declines the most.

While coal loses the largest share of its employment relative to the baseline, the electric utility sector sees the largest absolute employment loss. While employment in the sector stays relatively flat at about 300,000 through 2010, it drops off rapidly thereafter, to 169,000 in 2020, about 144,000 less than baseline levels. Again, this decline is due largely to the energy efficiency improvements throughout the economy resulting in reduced demand for electricity, together with an increasing share of electricity being produced through combined heat and power in other industrial sectors.

In contrast to the experience in the energy-producing sectors, energy-intensive industries generally suffer negligible losses or small gains under the policy package. The case of the primary ferrous metals sector (which includes the steel industry) is fairly typical of energy-intensive manufacturers. It faces rather mild impacts, with small employment losses in the early years, although it fully recovers by 2020. The difference relative to the baseline is never more than 0.5% in any given year.

Given that steel making is a fairly energy-intensive process, these results may seem counterintuitive. The relatively benign impacts are due mainly to three effects. The first is that the border tax adjustment on steel mitigates the erosion of the competitiveness of U.S. production relative to international markets. The second is improvements in energy efficiency. While the carbon tax increases the price per unit of energy consumed in the industry, the efficiency improvements allow steel producers to make steel with less energy, so that the price of steel increases by only 3.25% by 2020. Finally, the small reduction in demand that this price increase might otherwise cause is offset by increases in demand due to the overall increase in GDP.

In general, most industries see similar results. The construction, auto, trucking, and paper industries, for example, all see modest gains in employment relative to the baseline throughout the years studied, with the gains never rising to more than 1%. Construction prices do not increase relative to baseline. Auto prices rise by more than 10% in the final year, as does the labor requirement per car. The increase in per-vehicle labor requirements thus offsets the decline in vehicle consumption due to higher prices and a slight increase in imports.[48] The burden on the consumer of higher auto prices is substantially offset by lower fuel costs. Trucking prices rise slightly, but the demand for trucking services is relatively insensitive to price and depends mainly on the volume of goods to be shipped, which increases. The international competitiveness of the primary paper sector is maintained through border adjustments, and the increase in domestic price is small due to energy efficiency improvements.

Taken together, all of these modest impacts in the various sectors yield increased employment for the economy as a whole as well as for the manufacturing industries taken together. By 2020, employment in the manufacturing industries is about 1.3% higher than it otherwise would be (though it should be noted that this merely slows, and does not reverse, the shrinkage of manufacturing employment that is projected to occur in the baseline).

Employment increases in the service industries are slightly greater in percentage terms than those in manufacturing. However, the absolute number of jobs created in these sectors is considerably larger because the service sector constitutes a larger share of employment initially and is growing more rapidly in the base case.

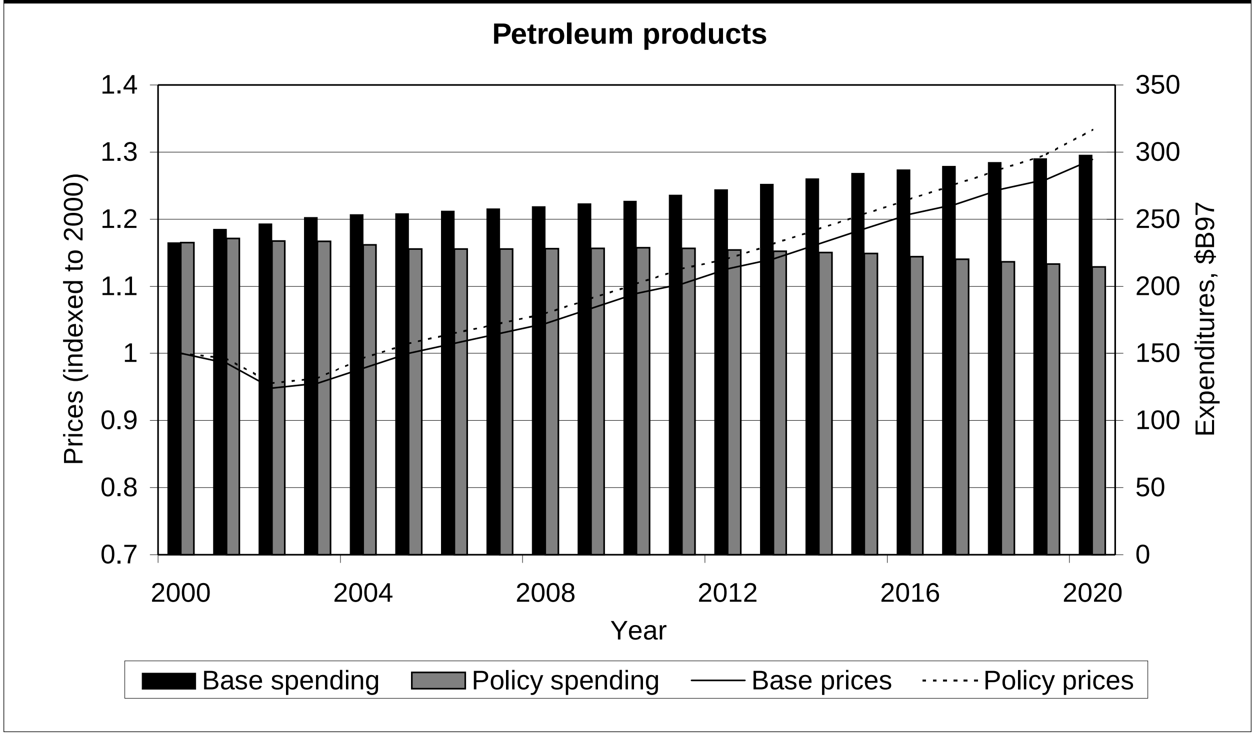
4.8. Energy prices and expenditures

While rising energy prices, induced either by taxes or by market forces, can induce energy consumers to become more efficient, they can also impose economic hardships on family budgets. Our modeling finds that, despite increases in energy prices, expenditures on energy fall substantially, and so family budgets are not adversely affected by rising energy bills. In fact, the opposite occurs. Over the 20-year forecast, for every dollar spent by households on energy-efficient appliances and cars, household energy bills fall by more than $4.[49]

The following graphs show the prices and total domestic expenditures on petroleum products, electricity, and natural gas. The lines indicate the price per unit in the base and policy cases, indexed to 2000 (i.e., expressed as a ratio to their 2000 prices). Increases in prices can be read on the left-hand vertical axes. The columns represent annual total expenditures, measured in billions of 1997 dollars. These values can be read on the right-hand vertical axes.

As **Figure 9** shows, prices for petroleum products (including gasoline, diesel, and home heating oil) fall in the initial years (reflecting a rebound from their current high levels) and then begin steadily increasing through 2020. In the baseline, prices in 2020 are just under 29% above their 2000 levels, while

FIGURE 9



in the policy case, the increase is about 33% relative to 2000. Relative to the baseline, gasoline prices in the policy case are about 1.4% higher in 2010 and about 3.4% in 2020.

At the same time, expenditures on petroleum products in the policy case are below the baseline in every year. Further, while the baseline shows purchases increasing in every year, expenditures actually fall through much of the policy case.

This trend helps illustrate some of the other results found. The most important of these is that the efficiency policies reduce the demand for energy and energy-intensive products, restraining the price increase that would otherwise be caused by the energy tax. The value of carbon tax payments from the petroleum industry as a share of industrial output is about 12.3% in 2020. Because the efficiency policies allow businesses and consumers to drive cars and trucks and heat homes and businesses with less energy than they used to, petroleum and other fossil fuels producers are unable to shift most of the burden of the tax onto energy consumers. Instead, they are forced to bear most of it themselves. This is seen in the fact that, while the total tax burden is 12.3%, the prices consumers face in 2020 increase by only 3.5%; the petroleum industry, domestic and foreign, pays about three-fourths of the energy tax.[50] Without the efficiency policies, energy consumers would be less able to reduce their demand and would likely face a much greater tax burden.

This can also help explain why sectors like trucking and other transportation industries do not face large reductions in output or employment while the petroleum refining sector does. On one hand, the increase in fuel prices is much lower than the $50 per ton tax might seem to indicate, and, on the other hand, efficiency increases allow them to continue operating with greatly lower fuel needs that offset much or all of the price increase.

The outcome seen above is similar to the experience for both electricity and natural gas. As shown in **Figure 10**, electricity prices grow almost uniformly through 2020 in both the baseline and policy case, with prices in the policy case about 6.5% higher than the baseline by 2020. By 2020, however, expenditures on electricity are about 54% of what they would be in the baseline.

The results for natural gas are similar (**Figure 11**), but prices rise higher and expenditures fall less than for gasoline and electricity. Both the baseline and the policy case show a large initial reduction in prices from their 2000 levels, again showing a rebound from their current high levels. Following this, prices in both cases begin to rise. By 2020, policy case prices are about 10% higher than their baseline levels, while expenditures are about 25% below the baseline.

This trend may seem counterintuitive, given that natural gas has a lower carbon content per unit of heat than either coal or petroleum. The total tax burden for natural gas is about 13.2%; with prices rising 10.4%, consumers bear most of the tax burden. The reason for this is that, with coal consumption falling, electricity generators do not cut back on natural gas consumption as much as they might otherwise, maintaining a relatively high level of demand for natural gas. While efficiency measures reduce demand overall, demand does not fall as much as it does for other energy products, so that prices increase more than for other forms of energy. Despite this larger increase in price, expenditures on natural gas fall well below their baseline levels.

4.9. Transition assistance

As mentioned above, the transition program is modeled in several ways, with two estimates of the number of eligible workers (total layoffs in impacted industries vs. layoffs actually caused by the program) and two different adjustment packages (two- to four-year income replacement plus retraining vs. five-year income replacement). The main impact of these differences is the amount of money that must be diverted from the carbon tax revenues to fund the program, and this varies with the number of eligible workers and package cost. The more funds diverted, the smaller the labor tax cut will be. (The difference between the methods has little impact on the macroeconomic forecast, with GDP differing by less than 0.16% in every year.) Throughout this paper, results are reported using the main package and the more inclusive eligibility standard.

Our primary estimation method (total layoff coverage) results in just under 1.6 million workers being eligible for benefits, 820,000 in the first 10 years and 776,000 in the last 10. Including the community transition funds, this means that $211 billion will be diverted to the transition program over 20 years, about 18% of the carbon tax revenues. The lower estimate (actual job loss) is considerably smaller, with only 162,000 workers being certified over the period. About 64,000 of these come in the first half of the forecast and 97,000 in the second half. Accordingly, the size of the fund is much smaller – only $21 billion over 20 years, less than 2% of the carbon tax revenues. Using the more expensive five-year payment package results in slightly higher payments, about 25% of tax revenues for the higher eligibility method and 2.7% for the lower method.

Yet another option is to use different eligibility standards for workers in different industries. Under this option, workers in energy industries (coal, oil, natural gas, and electricity) would be subject to the more inclusive standard, while workers in non-energy industries would be subject to the tighter standard, resulting in a hybrid of the two approaches outlined above. A commission or similar structure would need to determine eligibility for workers laid off from non-energy industries, as has been the practice for TAA

FIGURE 10

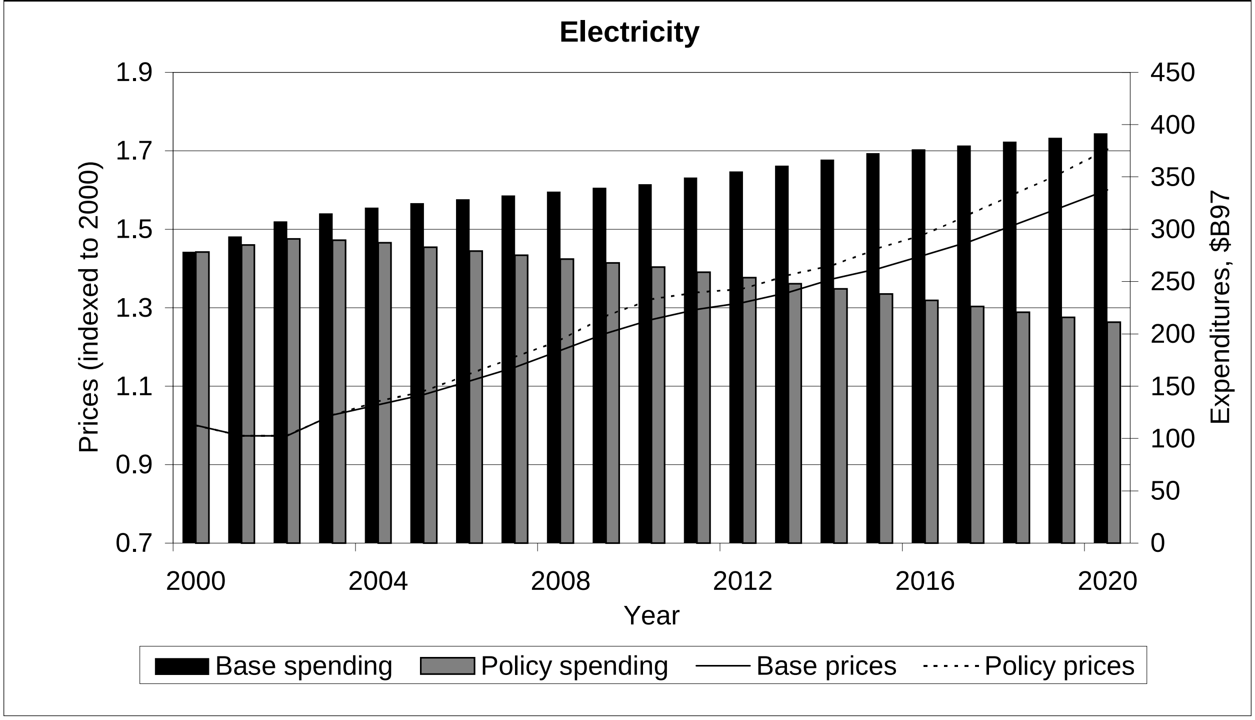
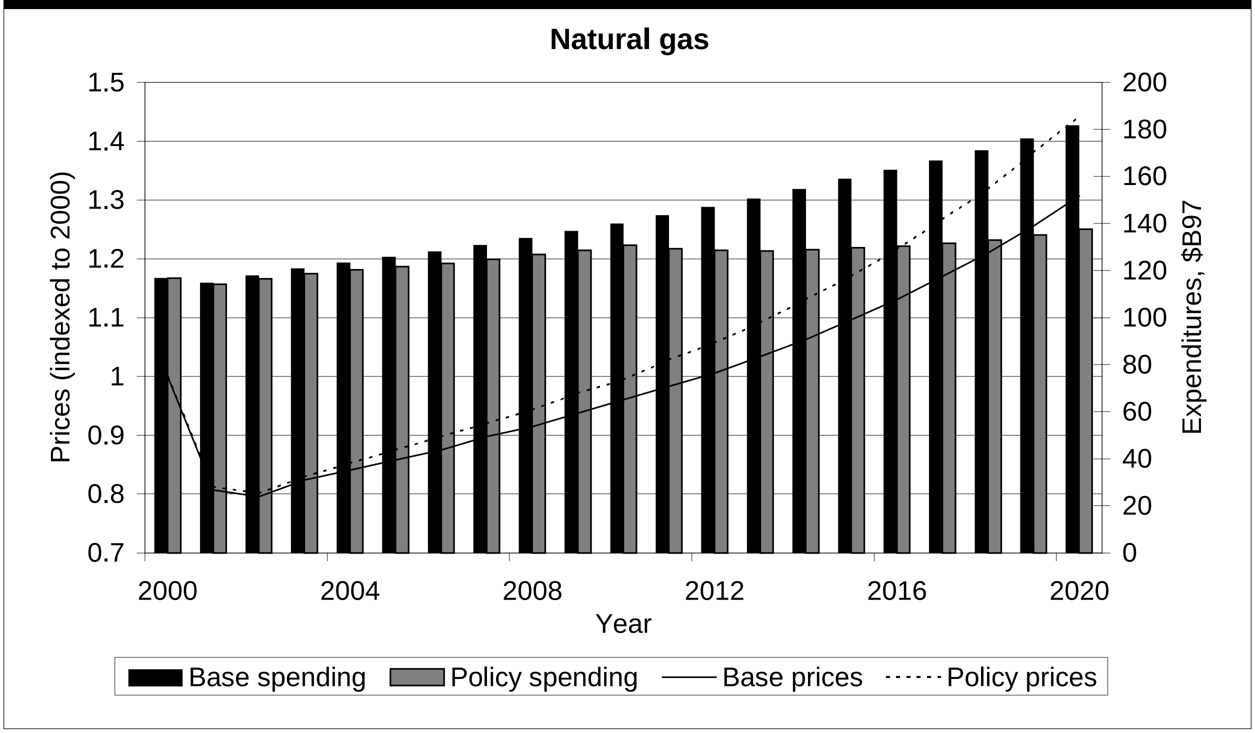


FIGURE 11



programs. We modeled such an approach assuming that the commission would certify three times the number of layoffs that are estimated to be actually caused by the policy package. This approach would require about $124 billion (11% of carbon tax revenues) for the primary package and $176 billion (15% of revenues) for the alternate package.

Finally, it is important to keep in mind that we have used conservatively high numbers whenever possible. The total layoff method we use to determine the size of the transition fund is conservative in two ways. First, it assumes that workers in energy-intensive industries will be eligible for the program regardless of the actual reason for losing their job. As mentioned above, the lower method is likely to be far more accurate in estimating the number of people who would be laid off due to the policy package. Second, it assumes that every eligible worker would take the package. Without reliable estimates of the number of workers who would likely enroll in the adjustment program, this assumption helps define an upper bound for the size of the program.[51] Because we likely overestimate the number of workers eligible for the package by a large margin, it is likely that the transition package could be made substantially more generous for workers who choose to take it without increasing the cost above our estimates.

5. CONCLUSION

Given the serious environmental and other side effects that come from continued dependence on fossil fuels to drive the economy, important questions are being raised about what steps could be taken to reduce U.S. consumption of coal, oil, and natural gas. Because the U.S. depends so critically on fossil fuels, one of the most important questions to be addressed is the impact such steps would have on workers and the economy as a whole.

Some studies that attempt to assess these impacts, usually in the context of reducing greenhouse gas emissions, have predicted serious economic harm as a direct result. A common element of these studies, aside from their ominous predictions, is the fact that they tend to rely on a single mechanism, a carbon tax or similar policy, to achieve their goals. Previous studies have generally found that a policy package that combines carbon/energy charges with revenue recycling and policies to promote energy efficiency and emerging technologies yields better economic results than do packages that achieve similar levels of emission reduction through single-instrument approaches, such as energy tax increases. Other important elements of a comprehensive energy efficiency and carbon reduction policy include policies to protect the competitiveness of energy-intensive industries and to compensate injured workers in the fossil fuel industries. Prior to this report, little work had been done to assess the broader economic implications of such policies, particularly in the context of a more comprehensive scenario.

This study attempts to help fill this gap by assessing the economic implications of a comprehensive approach to climate change and energy policy by modeling a policy package that includes elements of all of the types of policies outlined above. This analysis suggests that a policy package that uses a relatively modest tax on carbon to shift the tax burden away from labor and onto fossil fuel consumption, along with an array of policies designed to accelerate the adoption of carbon- and energy-efficient technologies can result in substantial declines in fossil fuel consumption and carbon emissions with modest but positive impacts on the macroeconomy. The results here do not suggest that these policies by themselves would be sufficient to bring atmospheric carbon concentration to sustainable levels, since this is clearly impossible for any one nation to achieve. Rather, the study assesses the economic impacts of a specific set of measures that can help reduce carbon and other emissions associated with fossil fuel consumption, and finds them to be largely positive.

While these results are promising, neither the costs nor the benefits of this approach are equally shared by all. Specifically, workers in fossil fuel and some energy-intensive industries will face an uncertain future as the demand for the products they make, and thus for their labor, declines. These losses can be mitigated to a certain extent by policies aimed at preserving the competitiveness of energy-intensive industries, but declines in employment for a few industries, severe in some cases, appear unavoidable. For this reason, the package modeled here includes a transition program aimed at helping laid-off workers and their communities in the transition to a more carbon- and energy-efficient economy.

While this study suffers from some limitations common to studies of this sort, and while the policy package modeled here may not be ideal, the results strongly indicate that a comprehensive approach is required to address the problems posed by dependence on fossil fuels. Especially when considered in context with other research in this area, these results illustrate that achieving carbon and energy efficiency will require a multifaceted approach that includes both economic incentives and technology promotion policies. The combination of the technology policies and carbon pricing yield the reductions in fossil fuel consumption and carbon emissions without the severe impacts on the macroeconomy seen in other research. Our findings suggest that the appropriate direction for both research and policy development lies in the exploration of comprehensive policy packages, as have been pursued in countries that have adopted stronger carbon reduction policies.

APPENDIX A: Labor-Environment Dialogue on Climate Change

The policy package detailed in this report was selected based in part on the fact that, of the options examined here, it seemed most likely to meet a set of criteria for a labor-friendly climate policy developed by the Working Group on Market Mechanisms and Just Transition of the Labor-Environment Dialogue on Climate Change, a project of the AFL-CIO.

In 1997, the AFL-CIO and a group of environmental organizations led by the Sierra Club and the Union of Concerned Scientists began a series of meetings called the Labor-Environmental Dialogue on Climate Change. (The authors of this report served as technical advisors.)

These meetings culminated in a Labor-Environmental Summit at the George Meany Center for Labor Studies on April 14-15, 1999. More than 60 trade union and environmental leaders attended. Summing up the meeting, AFL-CIO President John Sweeney and Sierra Club Executive Director Carl Pope said: “The transition in the global energy economy is threatening both workers’ rights and the climate. We commit ourselves to crafting together a package of worker-friendly domestic carbon emission reduction measures.”

The summit appointed several working groups to help fulfill this charge. One of these was the Working Group on Market Mechanisms and Just Transition, which ultimately adopted five criteria that a labor-friendly climate plan should meet. According to these criteria, such a plan should:

1. result in substantial energy savings and related environmental benefits, including putting the U.S. on a path toward a level of greenhouse gas emissions that can be sustained without dangerous changes in the global climate;
2. minimize negative impacts on employment and economic growth in the long term;
3. recognize the importance of strengthening the labor movement and preserving union jobs, including jobs in energy-intensive and fossil-fuel industries;
4. provide a complete, “make-whole” remedy for any jobs that may be lost as a result to the program, and assistance to communities that lose their primary economic base as a result of the program; and
5. be progressive in distribution of burden across income classes.

The Working Group did not select any particular emissions reduction target, but suggested that the U.S. should aim for a policy package that is feasible, makes economic sense, and puts the nation on a long-term path that combines steady carbon emissions reductions with robust economic growth.

APPENDIX B: Description of Sectoral Policies

This section provides a more detailed description of the package of energy efficiency technology promotion policies discussed in this report. The first four sections describe energy efficiency initiatives in four sectors: manufacturing, buildings, transportation, and electric generation. The fifth describes measures to reduce the emission of non-CO2 greenhouse gasses. These policies are, for the most part, taken from the Scenarios for a Clean Energy Future report’s advanced scenario (the CEF report). The transportation policies also include the measures in the corporate auto fuel efficiency (CAFE) sensitivity case from that report.

The CEF report should be consulted for greater detail on the policy package, which is described here only in summary fashion. However, in some cases the policies have been modified from the CEF advanced scenario to improve the economic or environmental benefit or to make them more worker friendly. Additional policies have been added from two sources: (1) feedback from our board of union advisors, and (2) the *Energy Innovations* report (Alliance to Save Energy et al. 1997) and related studies (World Wildlife Fund 1999; Geller, Bernow, and Dougherty 2000). Energy savings and investment cost estimates for these additional policies were calculated by Steve Bernow and Bill Dougherty of the Tellus Institute under contract with CSE. Those changes are fully described here. The added policies were chosen based on several criteria. First, that they had been studied adequately to have a solid basis for cost forecasts. Typically this implies that we look only at policies that have been advocated by a broad range of groups. Some have actually been implemented at the state/municipality level, and many have been introduced as federal legislation. The list is deliberately not exhaustive. Second, each policy has a negative cost of saved carbon over the life of the investment, using a 5% real discount rate. Note that this is a somewhat lower discount rate than is used by the CEF in some cases. This accounts for the wider range of policies available under the Tellus analysis, which is otherwise based on essentially the same model (NEMS) and modeling assumptions as the CEF. However, it should be observed that the average benefit-cost ratio for the various demand-side policies under this assumption is more than three to one. Thus, the package as a whole would be cost effective even under more pessimistic discount rate assumptions, though individual elements of it may not be.

B.1 Manufacturing sector policies

The manufacturing sector, which employs 21% of American workers, is a large, diverse, and essential sector of the U.S. economy. Since most of its products can be exported and imported (unlike many service industries in which production is inherently local), the manufacturing sector is highly exposed to international competition. Also, the manufacturing sector is a leading source of export-related jobs.

The manufacturing sector is also much more energy- and carbon-intensive than the rest of the economy. It produces 51% of total industrial emissions and roughly four times the emissions per job as the average for the rest of the economy.

The package described below is essentially the manufacturing portion of the advanced scenario in the CEF report. It differs in three respects. First, the switch to more efficient motors is accomplished partly by a scrappage bounty system, rather than through a pure regulatory approach. Second, the tightening of Clean Air Act standards is assumed to be accompanied by increased reliance on output-based regulatory approaches, tying allowable emissions to manufacturing production volumes. These two changes were made for greater workability and competitiveness reasons; they have a trivial impact on the emissions estimates. Finally, although the CEF report examined the potential for combined heat and power (CHP) and district heating systems for large, energy-intensive manufacturers, it did not examine the potential for cost-effective small-scale CHP among non-energy-intensive manufacturers and large commercial operations such as hospitals and universities. Based on *Energy Innovations* estimates as updated by Tellus, we assume an additional 26 GW of such capacity in 2010 and an additional 77 GH in 2020 of such applications, distributed between the industrial and commercial sectors.

Summary of policies

Voluntary agreements: strengthen existing voluntary sector agreements with associations and companies to achieve an energy efficiency improvement of 1.0% per year over the business-as-usual scenario.

Voluntary programs: increase motor, compressed air, steam, and CHP challenge programs and extend to smaller companies; expand floor space covered by Energy Star Building program by 100%; expand number of pollution prevention program partners to 1,600 by 2020 (from 700 in 1997).

Information and technical assistance: expand energy audit programs (Industrial Assessment Centers) and labeling programs.

Motors: mandate upgrades of all motors to Consortium for Energy Efficiency standards by 2020; provide bounties for scrappage of older motors (i.e., small payments to firms for each old, inefficient motor scrapped).

Clean Air Act: increase enforcement with emphasis on output-based approaches.

Investment enabling: expand Clean Air Partnership and line charges to 50 states; provide tax rebates of 50% of the salary of 10,000 energy managers by 2020; provide investment tax credit for CHP systems.

CHP policies: provide tax credits similar to those in the administration's Climate Change Technology initiative, extended beyond 2003; increase state grants through Clean Air Partnership Fund; expedite siting and permitting, interconnection standard in 2002.

Research and development: double cost-shared federal R&D expenditures: include new industries-of-the-future effort and further expand cross-cutting industrial efficiency R&D programs.

Industrial tax incentives: establish a 10% investment tax credit for new capital investments in energy-intensive industries and for advanced energy efficiency technologies, to accelerate the rate at which technological innovation diffuses into industries and to more quickly retire outmoded and inefficient production equipment and facilities.

B.2 Transportation sector policies

The transportation sector provides essential services without which the economy could not function. The transportation industry (auto, truck, rail, aviation, and shipping) is one of the nation's largest employers, especially when employment in related industries (motor fuels, gas stations, road building and repair, etc.) is considered. No solution to the climate problem is workable unless it includes a healthy domestic transportation industry. Moreover, the U.S. exports a significant number of automobiles, and climate protection goals should include increased exports of high-efficiency, low-emissions vehicles.

Yet the transportation sector is one of the largest sources, and is the fastest-growing source, of emissions of carbon dioxide, the major greenhouse gas. Partly as a result of relatively low gasoline prices in the U.S., American consumers have come to prefer larger, less fuel-efficient vehicles, and U.S. producers have become better at producing such vehicles. It seems likely that, in the long run, the U.S. will have to follow the rest of the world toward more fuel-efficient vehicles, though consumers here are likely to continue to prefer somewhat larger vehicles than in Europe. The policy package discussed here would seek to accomplish the transition to greater efficiency without the disruption of U.S. auto production and the loss of market share to foreign producers that took place in the 1970s as a result of the oil price shocks.

The package described below is essentially the transportation portion of the advanced scenario in the CEF report. It differs in three important respects from that proposal. First, it switches the tax credit for super-efficient vehicles from a consumption credit – which goes to a U.S. purchaser of high-efficiency vehicles, whether produced in the U.S. or imported – to a production credit, which goes to U.S. producers of energy-efficient vehicles, whether sold in the U.S. or exported. Second, because the advanced scenario still does not meet the overall goal of putting emissions from each sector on a downward path, this policy package incorporates the higher sensitivity analysis case for CAFE standards, which models larger increases in CAFE standards than the basic advanced scenario. This standard is a combined standard for cars and light trucks, starting at the current fleet average of about 24 miles per gallon and rising to 34 mpg in 2010 and then to 50 mpg in 2020. These fleet average numbers are approximately equivalent to auto standards of 48 mpg in 2010 rising to 68 mpg in 2020 and light truck standards of 30 mpg in 2010 and 42 mpg in 2020. (Note that these numbers include electric and other non-traditional vehicles). Finally, we project higher (but still quite low) penetration rates for cellulosic ethanol.

One component of the package – pay-at-the-pump auto insurance – will encourage faster rates of automobile turnover and greater automobile sales, while reducing the total cost of car ownership. In addition, the increased cost of building more fuel-efficient vehicles increases the employment required to produce them.

Summary of policies

Tax credits: implement vehicle purchase tax credits as proposed in the Clinton Administration's Climate Change Technology Initiative (CCTI) ($2,000 credit for vehicle that is two-thirds more fuel efficient than a comparable vehicle, for purchases in 2003 through 2006), but extended and switched to a production credit.

Ethanol: promote investment in cellulosic ethanol production.

Government purchasing: promote alternative fuels and efficiency in government fleet program.

CAFE increase: described above.

Pay-at-the pump: national "pay-at-the-pump" automobile insurance (providing a voucher for basic auto insurance coverage to all motorists using revenues from motor fuel taxes).

Traffic control: adopt intelligent air traffic system controls, including air traffic management improvements to reduce the time spent waiting "on line" on the ground and circling around airports.[52]

Research and development: double cost-shared federal R&D expenditures.

B.3 Buildings sector policies

The buildings sector includes activities in the commercial and government sector (distinct from manufacturing, mining, and others included in the industrial sector) as well as residential energy use, but not transportation. It includes lighting and HVAC in residential and commercial buildings themselves as well as appliances used within those buildings. The sector accounts for just over one-third of primary energy consumption. About two thirds of that comes from electricity, and about 25% comes from direct consumption of natural gas.

The buildings sector includes the entire commercial and government sector, which collectively contain most of the employment in the economy, 75% of all jobs. Energy-related jobs in the buildings sector are primarily in retrofitting, maintenance, and repair. In addition, there are manufacturing sector jobs associated with buildings sector policies in the construction trades, the production of HVAC equipment, and energy-using appliances. However, the primary job impact in the commercial sector should be from indirect effects from the increase in energy prices and the decreases in labor taxes.

Because of the various end-uses of energy in the buildings sector, some of the individual policies here will be very detailed. Many of the individual policies and implementations will, by themselves, have only a small effect on overall energy consumption, but taken together they yield large enhancements in energy efficiency and productivity. Most of the policies focus on increasing the rate of adoption of technologies that are currently commercially available and cost-effective over the life cycle of the equipment.

The policy package discussed here essentially follows the CEF advanced scenario, though it differs in three regards. First, with respect to building codes, this policy package assumes a 20% rather than a 15% whole-building improvement for space heating and cooling efficiency (and in the case of commercial buildings, lighting) from 2001 to 2010, and that half of new homes and commercial floor space is affected. These standards are tightened further in 2010, and we assumed that all the new homes and commercial floor space constructed after 2010 will be affected. Second, we assumed somewhat tighter equipment standards for transformers, refrigerators and freezers, furnaces and boilers, commercial packaged air conditioning equipment, gas ranges, and reflector lamps.[53] We assume these standards are issued and take effect without delay, except in the case of clothes washers where we allow a longer phase-in period given the controversy over the assumed standard. Finally, we assume a small national wires charge of 0.2 cents/KWh to go into a Public Benefits Trust Fund to be used to provide matching funds to states for demand-side management, renewables development, and other public benefits activities.

Summary of policies

Voluntary programs: expand voluntary programs such as Energy Star (e.g., appliances, HVAC, windows), Building America, and Rebuild America (building shells). Includes increased penetration as well as expansion of covered end-uses.

Building codes: increase enforcement of current building codes (MEC, ASHRAE) plus updated residential building codes for 2009.

Equipment standards: implement and expand coverage of equipment efficiency standards for both residential (NAECA) and commercial (EPACT) equipment.

Efficiency fund: generate public benefits funds from electric utility line charges. Application of funds includes financing for efficient buildings, upgrades, equipment (such as HVAC systems), and other demand-side management (DSM) programs in which financing is repaid through resulting energy bill savings.

Government purchasing: expand government procurement policies, including expanded purchases of renewable electricity and solar equipment; meeting of Federal Energy Management Program efficiency goals; and Energy Star purchasing.

Rooftop solar: implement Climate Change Technology Initiative tax incentives (e.g., 15% tax credit for rooftop solar energy systems) with longer phase-out periods.

Research and development: double cost-shared federal R&D expenditures.

B.4 Electricity sector policies

Electricity is critical to economic performance; a healthy and reliable generating sector is a prerequisite for continued economic and environmental health. Recent efforts to restructure the industry have put both electricity workers and consumers at risk. The policies discussed here are aimed at improving the efficiency of electricity generation without harming labor in the industry.

Electricity generation accounts for about one-third of all energy consumption and about a third of all greenhouse gas emissions in the U.S. Over one-half of energy consumed in the sector comes from coal, the most carbon-intensive fossil fuel. With current fossil fuel generation averaging 30-35% thermal efficiency, there is substantial room for progress in both the energy and carbon efficiency of the generation sector. The policies below are aimed primarily at improvements in the energy and carbon efficiency of central station generators and the use of electricity from renewable sources. Policies to improve the end-use efficiency of electricity consumption are reported in the consuming sectors.

The policy package is based on the CEF report, with three important exceptions. First, the package discussed here does not include proposals to accelerate or facilitate the move toward restructuring; instead, the policies are designed to work through the current industry structure. In particular, the move toward marginal cost pricing is assumed to be regulatory rather than market-driven. In addition, the proposed tradable renewable portfolio standard would be structured to encourage renewable generation by existing electric utilities rather than provide an incentive to outsource renewable generation to independent power producers.

Wind power siting on federal lands must include comprehensive consideration of recreational and conservation concerns. Net metering must be accompanied by improved equipment and safety standards to prevent injuries to utility workers from unexpected power surges.

Second, the policy package here assumes that tighter standards for particulate emissions, as proposed in the CEF, will be phased in starting immediately, rather than in 10 years. (We believe that least-cost energy decisions in the electricity sector are best made in the context of a multi-pollutant control strategy such as the four-pollutant approaches currently under consideration, and should be included in the policy package. However, we have not been able to implement such a strategy in the economic modeling effort reported here, which is based only on tightened particulate emissions.)

And third, the policy package assumes a more aggressive version of the renewable portfolio standard for wind, solar, geothermal, and biomass (including municipal solid waste and landfill gas), rising gradually to 10% of baseline generation in 2010 and then to 20% of baseline generation in 2020.[54]

Summary of policies

Tax credit: expand renewable production tax credit to 1.5 cents per kWh for all non-hydroelectric renewables through 2004.

Renewable portfolio: adopt a renewable portfolio standard of 7.5% from 2005 to 2008 with a cap of 1.5 cents per kWh, as per the Clinton Administration's April 1999 proposal.

Land use: Facilitate wind generation citing on government lands.

Research and development: double federal R&D budgets for both renewable and fossil generation technologies.

Net metering: adopt up to 5% net metering for residential PV generation.

Pricing: adopt full marginal cost pricing by 2008.

Pollution standards: gradually reduce SO2 caps to 50% of current levels from 2010 to 2020; tighten standards for PM and other criteria pollutants.

B.5 Materials recycling and methane emissions reduction policies

Emissions of methane, a powerful greenhouse gas, when weighted for global warming potential, accounted for 9% of all U.S. greenhouse gas emissions in 1999 (EIA 2000a). With a global warming potential 21 times that of carbon dioxide, methane emissions from landfills, leaks from natural gas and oil production and distribution, livestock manure management, and coal mining are expected to grow to 172 MMtCE (million metric tons of carbon equivalent) by 2010. However, recent studies by the U.S. Environmental Protection Agency and others indicate that methane emissions can be substantially reduced at very low cost (EPA 2001). In fact, if cost-effective policies are enacted, emissions reductions of 66.9 MMtCE can be achieved in 2010 at a cost of $448.8 million.

Moreover, recapture of methane for energy use can be profitable and could play a part in the development of a national energy security strategy. It is therefore advisable that low-cost policies to reduce methane emissions be pursued in concert with carbon emission reductions to meet the U.S. emissions reductions commitment agreed to under the Kyoto Protocol. **Table B1** summarizes the sources of methane emissions, achievable reductions, and the costs of those reductions.

B.5.1 Methane recapture from landfills

Policy: Extend and expand landfill rule, Section 29, EPA Landfill Methane Outreach.

Stimulation of efforts to recapture methane from waste decomposition in landfills would target the largest single source of methane emissions in the U.S. Extension of the landfill rule and the tax credit included in Section 29 of the Windfall Profits Tax Act to small landfills while continuing EPA's landfill methane outreach program would result in 26.1 MMtCE avoided in 2010 compared to 1990 levels. In 2020 emissions of approximately 30.8 MMtCE could be avoided in comparison to 1990 levels. In addition to reducing methane emissions, recapturing methane from landfills for electricity production could offset emissions of greenhouse gases and air pollutants from fossil fuel combustion. Currently only 270 out of over 6,000 landfills in the country recover methane for energy use (EPA 1999).

B.5.2 Natural gas system leaks

Policy: Continue EPA Natural Gas STAR Program, encourage technology adoption.

The second largest source of methane emissions is leaks in natural gas pipelines (natural gas is 95% methane)

TABLE B1
Summary of achievable methane emissions reductions

Industry by inforum category	1990 Emissions levels (MMtCE)	2010 reductions below 1990 levels (MMtCE)	Annual cost in 2010 ($1997 millions)	2020 reductions below 1990 levels (MMtCE)	Annual cost in 2020 ($1997 millions)
4 Natural gas extraction[a]	18.19	5.69	-9.05	5.36	-8.87
67 Gas utilities[b]	14.71	4.61	-7.32	4.34	-7.18
3 Coal mining[c]	24	16.00	73.1223	15.30	79.34
1 Agriculture, forestry, and fisheries[d]	14.9	2.30	180.1107	0.30	219.10
68 Water and sanitary services	56.2	26.10	211.9428	30.80	151.94
Totals	**128.00**	**54.70**	**448.80**	**56.10**	**434.33**

a. Landfill emissions avoidance costs are calculated as the amount that would have to be added to the energy market price on a dollar per ton of carbon-emissions-avoided basis to make the sale of methane break even.
b. Natural gas emission avoidance costs are calculated as the amount that would have to be added to the energy market price on a dollar per ton of carbon-emissions-avoided basis to make the sale of methane break even.
c. Coal industry costs are calculated as the amount that would have to be paid to the coal mining industry on a dollar per ton of carbon-emissions-avoided basis to pay for the extra costs incurred by emissions reductions strategies.
d. Manure management emission avoidance costs are calculated as the amount that would have to be added to the energy market price on a dollar per ton of carbon-emissions-avoided basis to make the sale of methane break even.

during production, transmission, and distribution. Emissions from this source are forecasted to grow to 37.9 MMtCE in 2010, up from the 1990 level of 32.9 MMtCE as natural gas consumption increases (U.S. DOE (2000) projects a 1.6% increase in gas consumption until 2020). However, EPA has identified 118 separate technologies under the Natural Gas STAR Program that decrease leakage from pipelines and more efficiently convert fuel to energy. Adoption of these technologies could slow the rate of methane emissions relative to natural gas consumption. Using 1996 energy market prices for the value of the incremental increase in natural gas retained and sold from leak avoidance, a reduction of 10.1 MMtCE (30% of projected emissions) in 2010 could be achieved at no cost to the economy (EPA 1999).

B.5.3 Coal mining

Strategy: Recover methane from underground mines for sale as natural gas or on-site power generation. Catalytic oxidation in ventilation systems.

Methane released when coal is mined accounted for 10% of total methane emissions in 1997 and is expected to account for a larger share in 2010. Increased methane recovery and the exhaustion of particularly gassy mines reduced emissions from this source in 1997 to 18.8 MMtCE from the 1990 level of 24.0 MMtCE. Baseline emissions growth from coal mines is expected to reach 28 MMtCE in 2010 due to coal mining in deep mines. Emission reductions equal to 37% of baseline 2010 emissions (10.36 MMtCE) from coal mines are achievable at no cost. In 2010, the cost of all methane emissions reductions that can be achieved through economically and technically feasible recovery technologies is $71.9 million (EPA 1999).

B.5.4 Livestock manure

Strategy: Support use of anaerobic digestion technologies for on-site electricity generation.

The primary sources of livestock manure methane are dairy, cattle, and hog farms that use liquid management systems. In 1990 14.9 MMtCE of methane was released from livestock manure; in 1997 that figure reached 17.0 MMtCE/year. Emissions are expected to rise to 22.3 MMtCE in 2010 due to animal population growth and prolif-

TABLE B2
Costs and carbon savings from recycling programs

Industry category	2010 costs ($1997 millions)	2010 reductions (MMtCE)	2020 costs ($1997 millions)	2020 reductions (MMtCE)
Paper	146.9	0.84	146.9	0.84
Plastic products	-52.8	0.54	-52.8	0.54
Stone, clay, and glass	209.43	0.48	209.43	0.48
Metal products	-346.67	2.02	-346.67	2.02
Total	-43.1	38.8	-43.1	38.8

eration of liquid management techniques. Recapturing methane from manure decomposition for sale on the electricity market or for onsite generation could avoid 14% of baseline 2010 emissions (3.1 MMtCE) at no cost.

B.5.5 Recycling programs

Strategy: Encourage recycling of office paper, corrugated cardboard, household paper waste, aluminum and steel cans, and plastics.

Substantial greenhouse gas emission reductions can be achieved via better management of municipal solid waste (MSW). As noted above, when disposed of in landfills, organic wastes such as paper products, food waste, and yard trimmings decompose anaerobically, thereby forming methane in landfills. Failure to recycle substantial percentages of MSW also results in greater energy use because more energy is needed to create new materials from newly extracted resources than is needed to create the same materials from recycled waste. Recycling such items as aluminum and steel cans, various paper products, and plastic containers can therefore result in a net energy savings (Ligon 1998). Estimates indicate that energy savings from recycling could amount to approximately 3.9 million metric tons of carbon emissions avoided per year at a net benefit of $43 million, given current recycling technologies. These benefits/costs accrue to the paper industry; the stone, glass, and clay industry; the metal products industry; and the plastics industry in the form of energy savings and lower costs of materials (see **Table B2**).

APPENDIX C: Change in employment, base case to policy case

The next two tables provide information about employment and layoffs, respectively. **Table C1** shows employment by industrial sector in 2000 and in both the base and policy cases in 2010 and 2020.

One cannot equate differences between the two scenarios to new hires or to layoffs. Rather, these numbers represent the changes in job openings or job slots and do not necessarily reflect layoffs or hires. In sectors where employment declines relative to the baseline, for example, some of this difference will be due to firms not replacing workers who retire, quit voluntarily, or leave for other such reasons. Even industries with stable employment levels normally see substantial turnover in the course of a year, as reductions due to retirement, voluntary movements by workers, release for cause, and the like are offset by new hires. Increases in workforce size can therefore be achieved by increasing the hiring rate, increasing the retention rate, or both.

Table C2 shows estimates of the average annual layoffs in excess of normal turnover that would result from the policy scenario discussed in this paper. It shows only those industries in energy-intensive sectors that have positive layoffs. Note that some energy-intensive industries, such as primary metals, chemicals, primary paper, and stone, clay, and glass, are not shown in the table because their employment levels do not decline in the forecast by more than a normal turnover amount. These industries are all treated as eligible for transitional assistance. In the calculation used to estimate the size of the transition fund, we assumed that we cannot tell policy-related layoffs from other layoffs, so a significant number of workers in all of these industries receive transitional assistance.

Several important caveats concerning these layoff figures should be observed. First, these represent only the

TABLE C1
Employment by sector (thousands of jobs)

Sector label	2000	Baseline 2010	Policy 2010	Baseline 2020	Policy 2020
Agriculture, forestry, & fisheries	3,640	3,552	3,554	3,356	3,371
Coal mining	87	53	24	46	12
Other mining	168	183	180	175	171
Oil & gas wells	803	800	780	1,608	1,407
Construction	7,750	8,940	8,978	9,504	9,578
Food products	1,810	1,789	1,793	1,831	1,845
Tobacco products	39	24	24	15	15
Textiles & apparel	1,277	915	911	702	703
Paper	682	774	778	830	839
Printing & publishing	1,651	1,862	1,873	1,949	1,977
Drugs	262	293	294	337	340
Other chemicals	734	821	822	689	695
Petrolium refining	125	139	125	97	76
Rubber & plastic products	1,056	1,061	1,067	1,003	1,021
Stone, clay, & glass	601	592	589	576	554
Primary ferrous metals	426	425	425	354	356
Primary nonferrous metals	367	462	461	510	512
Machinery & equipment	2,948	2,405	2,410	2,068	2,145
Computers & office equipment	414	315	316	227	232
Motor vehicles & parts	1,095	991	997	921	925
Aerospace & marine	700	718	728	774	799
Other manufacturing	5,611	5,496	5,516	5,327	5,427
Railroads	229	177	164	140	125
Trucking, highway passenger transit	2,891	3,524	3,529	4,023	4,049
Other transport services	2,128	2,928	2,932	3,518	3,541
Communications	1,599	1,306	1,319	1,079	1,097
Electric utilities	308	401	305	314	169
Gas utilities	115	147	138	187	142
Water & sanitary services	289	372	373	483	485
Retail & wholesale trade	25,308	26,243	26,339	26,075	26,277
Resturants, hotels, & amusements	12,695	14,753	14,840	16,252	16,470
Finance, insurance, & real estate	8,032	9,913	9,998	10,934	11,081
Professional services	5,210	4,204	4,220	3,422	3,461
Computer & data processing	1,891	2,619	2,652	3,081	3,220
Advertising & business services	7,701	9,828	9,850	10,829	10,929
Medical & nursing	11,114	12,347	12,409	14,024	14,174
Education, social services, membership org.	8,049	9,004	9,111	9,675	9,866
Other services	3,975	4,737	4,819	5,630	5,770
Federal, state, & local government	17,563	19,151	19,272	21,555	21,693
Total	**141,343**	**154,263**	**154,917**	**164,119**	**165,548**

layoffs that result from the policy scenario. Most of these industries will have much higher levels of layoffs in the base case than indicated here, due to base-case changes in employment levels and to industry restructuring; however, these layoffs are not captured here. Second, there are several uncertainties around these estimates besides those inherent in our macroeconomic forecasts. For example, these estimates are extremely sensitive to the assumed rate of voluntary turnover. We use a conservative value of turnover – 3% per year – equal to the average rate of voluntary turnover due to retirement alone, based on exiting demographic data. Raising the assumed rate of voluntary turnover

TABLE C2
Program-induced layoffs in impacted industries

Industry number	Industry	2001-10 Average annual layoffs	2001-10 % average layoffs	2011-20 Average annual layoffs	2011-20 % average layoffs
2	Metal mining	-	0.00%	355	0.78%
3	Coal mining	4,715	6.78	657	1.38
5	Crude petroleum	31	0.00	-	0.00
6	Non-metallic mining	5	0.00	-	0.00
24	Petroleum refining	658	0.51	2,124	1.80
35	Engines and turbines	27	0.04	50	0.08
59	Railroads	281	0.14	35	0.02
61	Water transport	-	0.00	-	0.00
63	Pipeline	261	2.78	258	5.47
66	Electric utilities	402	0.12	6,255	1.76
67	Gas utilities	42	0.04	-	0.00

to 5%, equivalent to assuming a 2% annual rate of voluntary quits not associated with retirement, would lower these estimates by an average of 43%. On the other hand, these estimates assume that reductions in employment can take place smoothly. To the extent that industry contractions take place by closing the least profitable plants rather than by reducing workforce at existing or proposed facilities, layoffs could exceed these levels, as the closing of entire plants cannot normally be accomplished through retirement and other voluntary force reductions. We use the low voluntary turnover rate in order to help offset these other factors to provide as accurate an assessment as possible.

Note that, for the coal industry, 2001-10, the baseline employment declines faster than the 3% annual turnover rate we use. Thus, the figure in Table C2 represents the sum of the program-induced layoffs, equal to approximately 2,900 jobs per year, and the excess of baseline employment reductions over estimated turnover, equal to approximately 1,800 jobs per year.

Endnotes

1. See, for example, Center for Energy and Economic Development 2000.

2. See EIA 1998; WEFA 1998; Consad Research Corp. 1998; Charles River Associates 1997, 1999; and Scott 1997.

3. One previous U.S. study (Hoerner and Mutl 2001) analyzed the combined impacts of revenue recycling, technology policy, and border adjustments. However, this study used an input-output model that, though well-adapted to estimating sectoral impacts, cannot capture GDP or aggregate employment effects. The conclusions of that study broadly echo our own.

4. See Beaumais and Bréchet 1993; Bossier and Bréchet 1993; DRI et al. 1994; Köppl 1999; Köppl et al. 1996; Lutz 2000; and Meyer and Ewerhart 1998. The last two of these studies employ a model similar in structure to the LIFT model used here.

5. These results contrast with those of previous studies conducted without revenue recycling, without technology policy, or both. Studies that impose energy taxes with neither revenue recycling nor technology policy generally find GDP and employment losses. Such studies are briefly reviewed in section 2.1.

6. See Section 3 and Appendix C for a more complete presentation of these results.

7. See Section 2.1 for a discussion of the limitations of the modeling approach.

8. See, e.g., Council on Environmental Quality, *Environmental Quality: The 25*th *Anniversary Report of the Council on Environmental Quality* (1994-95) for good summaries of long-term U.S. air and water quality trends.

9. A comprehensive survey of the scientific literature on climate change is contained in the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (2001). The IPCC conclusions were recently verified by an independent assessment by the National Academy of Sciences (2001).

10. It is important to observe that, as oil prices (including domestic oil prices) are set in world markets, the vulnerability of consumers and businesses (other than the oil industry) to oil price shocks is a function of the amount of oil they consume as a share of their total consumption or costs, rather than of the share of imports in domestic consumption. While the U.S. economy may not be able to function without substantial amounts of oil for the foreseeable future, reducing its dependence on oil reduces the nation's vulnerability to large swings in world oil prices. The United States has made some progress along these lines in the last 25 years, and oil price spikes similar to those of the 1970s would not have the same crippling economic effect if they were to occur today. However, as recent events demonstrate, swings in world oil prices can still have a significant effect on household budgets and the economy.

11. Or the revenue from economically equivalent auctioned tradable carbon emissions permits.

12. Some have suggested that the primary compliance mechanism for the U.S. should be to buy emission reductions from developing countries rather than reduce domestic emissions. This approach may help reduce greenhouse gas emissions in the short run, but it could also provide a source of funds, financed by American consumers, to relocate manufacturing facilities abroad. On the environmental side, unlike domestic emission reduction targets, international trading provides little incentive to develop new clean energy technologies. It therefore achieves cheap reductions in the short run but reduces the opportunity for cost-effective reductions in the long run.

13. See EIA 1998; WEFA 1998; Consad Research Corp. 1998; and Charles River Associates 1997, 1999.

14. See, e.g., WEFA 1998 and EIA 1998. For an analysis of the WEFA study, see Barrett 1999. For a critical comparison of major studies focusing on the limitations of single-instrument approaches, see Laitner 1999.

15. See Hoerner and Bosquet 2001; Parry and Bento 2000; Parry, Roberson, and Goulder 1999; Repetto, and Austin 1997; and Shackleton et al. 1996.

16. Good surveys of these studies can be found in Interlaboratory Working Group 2000 and IPCC 1996. See also Lovins and Lovins 1997; OTA 1991; Alliance to Save Energy et al. 1997; Tellus Institute 1998; World Wildlife Fund 1999; and Geller, Bernow, and Dougherty 2000.

17. This has been shown both theoretically and empirically. For good discussions of the theoretical implications of positive technological externalities, see Roemer 1986a, 1986b and Grossman and Helpman 1991. For a review, see Helpman 1992. The substantial weight of empirical studies shows that returns to research and development are far in excess of measured private rates of return. See, e.g., Griliches 1992, Mansfield 1996, and Boskin and Lau 1992.

18. For a review of this literature, see Sanstad, DeCanio, and Boyd 2001.

19. In the alternative, this could be implemented as a set of auctioned carbon permits, provided the other features of the tax described below, such as border adjustments and the equalizing charge, could be administered through the permit system.

20. The equalizing charge for each year is set equal to the average charge on fossil electricity in that year.

21. Unless otherwise noted, all dollar figures are in real 1997 dollars.

22. The credit would offset payroll tax payments through a reduction in income tax payments. The reason for using an income tax credit rather than directly reducing payroll taxes is to avoid changing the flow of revenues to the Social Security system, which would therefore be unaffected by this proposal. This credit would be refundable, i.e., low-income taxpayers who do not have much income tax liability would still get the value of the credit refunded to them, like the existing Earned Income Tax Credit.

23. A good review of the literature is contained in Edmonds, Roop, and Scott 2000.

24. For those cases in which the modifications to the CEF policies had a substantial impact on cost or emissions, the cost and emissions estimates were performed for us by the Tellus Institute. All modifications to the CEF advanced scenario are described in detail in Appendix B.

25. The CEF report is an updated and expanded version of the earlier study, Interlaboratory Working Group 1997.

26. The CEF advanced scenario includes analyses of a number of sensitivity cases to explore the implication of various alternative policies on prices and emissions. We used the scenario that included a higher corporate average fuel economy (CAFE) standard for cars and trucks because our goal was to put energy use and emissions in each of the major sectors on a path toward sustainability, and this required stronger measures in the transport sector, which has the greatest emissions growth in the baseline case.

27. See Romm 1999 for more examples of firms that have employed such technologies and the results.

28. This problem is most severe in the early-middle portion of the plan (roughly years five through 15), when the market mechanism has been fully phased in, but there has not yet been adequate time to fully implement the energy-efficiency improvements.

29. In our modeling, we assume that all eligible workers participate in the program. For more on the design of transition programs, see Barrett 2001a.

30. This puts average estimated program expenditures at about $20 billion per year. This is far in excess of current and past programs like Title III of the Job Training Partnership Act, which was funded at about $1.2 billion in 1997, and the Trade Adjustment Assistance Program, which was funded at about $300 million in 2000.

31. See U.S. Department of Labor 1995, 1998; and Peterson 1993.

32. Economic development programs vary widely in effectiveness and cost per job. Tax cut programs geared toward creating a better environment for industry have been shown to cost in the range of $1,906 to $10,800 per job created (Bartik 1992). Business incubation works are somewhat less expensive ranging from $1,500 to $2,000 per job created (Molnar 1997). EDA Public Works programs have been estimated to cost $4,857 per job (Burchell et al. 1997). Microenterprise development programs range between $4,114 - $6,155 on a cost per job basis (Economic Development Administration 1998). Given these findings, allocating $10,000 per job lost is at the high end of funding for economic adjustment.

33. See, e.g., “LIFT: Inforum’s Model of the U.S. Economy,” *Economic System Research*, 3(1), 1991.

34. Available on the web at http://inforumweb.umd.edu/Workpapr.html. For a comparison of the Inforum LIFT model to other modeling approaches, see Monaco 1997.

35. That is, for each fuel, the fuel intensity in each industry and sector was multiplied by the ratio of energy-efficiency improvement for that fuel and sector from the CEF report (the ratio between the use of that fuel in that sector in the CEF advanced scenario, as adjusted by the policies in Appendix B, divided by the use in the CEF baseline).

36. In order to maintain government budget neutrality and to ensure that our results were not influenced by external demand stimuli, the government program expenditures are deducted from the carbon tax receipts before taxes are cut, and the increased cost of capital to private firms is reflected through appropriate changes in prices and profits, as calculated by the model.

37. Demographic data from the Census Bureau shows that over the next 20 years, just over 3% of the manufacturing workforce will turn 65 each year. Assuming an average retirement age of 65, this provides a conservatively low estimate of voluntary exits.

38. See Goulder 1995; Parry and Bento 2000; Parry, Roberson, and Goulder 1999; and Mabey and Nixon 1997.

39. See Repetto and Austin 1997; Mabey, Hall, Smith, and Gupta 1997; Shackleton et al. 1996; Zhang and Folmer 1998; and Hoerner and Bosquet 2001.

40. A “grandfathered” permit system is one in which emissions permits are distributed to emitters at no charge, usually based on past emissions levels.

41. For surveys of more recent studies, see Interlaboratory Working Group 2000.

42. The *Scenarios for a Clean Energy Future* study (Interlaboratory Working Group 2000) on which we base most of the technology change estimates consistently forecasts actual penetration of particular technologies under its proposed policy package, using market penetration models and similar tools. In this it is an advance on many previous bottom-up studies, which should perhaps be regarded as studies of what is technologically feasible rather than technology forecasts *per se*.

43. There are also a handful of hybrid models where engineering and economic components are integrated, such as the Markal-Macro model and the Argonne National Laboratory's Amiga model. These have generally yielded results that are more similar to engineering models, i.e., showing emissions reductions which are achievable at a net benefit. For results from these two models, see Laitner 1997 and Hanson and Laitner 2000. An early study is the linking of MENSA (Australian regionalized version of MARKAL) and an input-output study in James and Musgrove et al. 1986. Another good example of linking a simplified bottom-up model is the HERMES-MIDAS model; see Capros et al. 1990.

44. We plan on undertaking additional analyses outside of the model framework to look at impacts on specific sectors such as rail and auto to attempt to account for these effects.

45. We assume that foreign auto makers selling in the U.S. market would have to meet the same standards as U.S. auto makers but that they will be able to do so at half the additional cost of domestic producers. We employed this conservatism to address the concern that foreign producers may have a significant head start in producing fuel efficient automobiles.

46. Absent other environmental policies, pollutants that are more closely tied to coal emissions, such as mercury and sulfur, will generally see a more than proportional decrease relative to carbon emissions. On the other hand, the interaction of carbon limits with some environmental policies such as the existing sulfur dioxide emissions trading could result in smaller reductions, unless the caps were tightened proportionately. However, carbon dioxide emission reduction policies would make implementation of such further reductions in other pollutants less expensive relative to the base case.

47. The amount of recoverable oil in ANWR is highly uncertain, though estimates hover around 3.5 billion barrels of economically recoverable oil, with roughly half recoverable in the first 20 years. For a high-volume but efficient recovery plan, production peaks in about 20 years, then falls. See EIA 2000b.

48. Although imports would also have to meet the new standards and so would have increased production costs, we assume that the substantial experience edge foreign producers have in producing high-mileage vehicles would result in a lower per-vehicle cost of compliance.

49. This is the sum of present-value costs and benefits over 20 years, using a 7% discount rate.

50. Note that similar calculations show that more than 90% of the labor tax cut accrues to workers.

51. While there are assessments of recent transition assistance programs that include participation rates, we do not consider these to be useful for the purposes here. In large part, this is due to the fact that past programs have been substantially less generous than the one proposed here. Title III of JTPA, for example, in 1996 spent less than $4,000 per worker, including program overhead. From 1995 to 1996, Title III served no more than 13% of the eligible population (Hipple 1997; U.S. Department of Labor 1998).

52. Intelligent motor vehicle traffic controls could also be included in those cases where it can be clearly shown that the efficiency gains due to improvement in the efficiency of traffic flow is not simply offset by increased traffic, as they seem to have been with some existing intelligent traffic systems.

53. Note that, since the 2001 *Annual Energy Outlook* that forms the basis of the baseline case was issued, the Department of Energy has issued new standards for florescent light ballasts, water heaters, and central air conditioners and heat pumps, at slightly lower levels than assumed here. Thus, a portion of what we consider the policy case in this area has already been adopted.

54. This level for the RPS was selected because it was within the range of existing federal legislative proposals and so had been well studied. Capital costs were based on cost assumptions from the Energy Information Administration's *Annual Energy Outlook 1999* and reflect NEMS's regional multipliers and technology learning parameters. Fixed operations and management (O&M) costs were also based on *Annual Energy Outlook 1999* assumptions. The mix of non-hydro renewables was modeled explicitly for 2010 in NEMS and is summarized below. The mix is similar in 2020.

	2010 (twh)	2010 (%)
Wind	197	57%
Solar	4	1%
Geothermal	43	12%
Biomass	105	30%
Total	348	100%

It should be stressed that, although this is the mix forecast by Tellus using the NEMS model, the policy package we have analyzed does not force this precise mix. Instead, it allows the utility industry to purchase a least-cost mix based on the cost of various renewable technologies as they emerge from the market.

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