REDEFINING PROGRESS

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WHAT'S FAIR?
WORKERS, INVESTORS, AND CLIMATE CHANGE

JANUARY 2000

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ACKNOWLEDGMENTS

The authors thank Maureen Kennedy, Christine Ervin, Ansje Miller, and Paige Brown for their helpful comments on this paper.

Redefining Progress would also like to thank our committed supporters who have made possible this and other work on climate change: the John Merck Fund, the New York Community Trust, V. Kann Rasmussen Foundation, Rockefeller Brothers Fund, Turner Foundation, Wallace Global Fund, and generous individual donors.

Redefining Progress thanks the William and Flora Hewlett Foundation and Surdna Foundation for their general support.

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I. INTRODUCTION

Redefining Progress has previously published two discussion papers on the topic of climate change. Each paper is intended to foster broad public discourse on the type of future Americans desire, and how to best achieve it. *The Economics of Climate Change* (October 1997), by Steven J. DeCanio, explores the common ground for reasonable policies to control human-induced climate change. "What's Fair? An Equity Framework for Global Climate Change" (March 1998), by Eileen Claussen, discusses fairness issues on a conceptual level applicable between nations as well as within nations. This paper—the third in the discussion paper series—asks if fairness can help to simplify issues concerning workers and investors in the United States, and finds that it can.

WHY SHOULD I READ THIS PAPER?

Most public policy decisions are complex, and final decisions are based on many different considerations. Any decision includes an explicit or implicit attitude about fairness (equity) issues. Most of the U.S. discussion of climate change policy, however, has focused almost exclusively on its costs and benefits. This paper is worth reading because it explains two important ways that fairness or equity issues may affect the policy decisions that are made. First, fairness suggests that this generation of Americans should undertake significant action to reduce emissions of greenhouse gases (GHGs) even if doing so is costly (to this generation). Unless the costs are exorbitant, Americans have historically chosen to pay for fairness (for example, the Americans with Disabilities Act). This paper argues that as a matter of principle, failure to act is unfair, and as a practical matter, acting to control climate change is affordable.

Second, whatever our beliefs are about fairness or who should or should not be compensated, adoption of climate policy can create a revenue stream from which we can, if we wish to, generously compensate all who are deserving, and fund an accelerated technological transition to renewable energy sources. This is important because it means that we can allay the fears of many groups that they will bear a disproportionate share of the social cost of climate policy. Although it will be difficult to assess which workers and investors are hurt, the revenue stream created by well-designed climate policy is large enough that we can, if we wish to, give the benefit of the doubt to many of the workers and investors who may seek compensation. Similarly, the revenue stream from well-designed policy is large enough to fund public assistance (for example, research and development expenditures, or tax credits for some types of machinery) for the technology transition that will be required to reduce climate change.

WHAT DO "CLIMATE CHANGE" AND "CLIMATE POLICY" MEAN IN THIS PAPER?

The climate of planet Earth was changing long before humans inhabited it. But human activities are now contributing to climate change in an adverse way. Although it has been difficult for the 2,500 scientists of the United Nations Intergovernmental Panel on Climate Change (IPCC) to reach consensus on this point, they did so in 1995: ". . .the balance of evidence suggests that there is a discernable human influence on global climate." The IPCC's "best guess" is that we will experience warming of about 3.5 degrees Fahrenheit by 2100, which would be a faster rate of warming than any experienced during the period in which modern human civilization developed (the last 10,000 years). A warmer Earth speeds up the global water cycle. This means more evaporation and precipitation, and probably more droughts, torrential rains, and floods.[1]

Climate change in this paper refers to human-induced effects, including an increase in mean temperature, an increase in the occurrence of extreme weather events, and changes in precipitation or other climatic patterns.

Although significant disagreements exist about the monetary value and distribution of impacts of human-caused climate change, there are no credible studies that say climate change will benefit American citizens overall. Common sense tells us that climate change is costly: even modest change in climate patterns requires individuals, businesses, and others to adjust to these changes, and paying for adjustments means that money is taken away from other uses. For example, the range of some diseases will expand, requiring vaccinations to be obtained in areas where they were not needed in the past.

Climate policy cannot stop climate change because it is already underway and natural systems require decades (in some cases centuries) to remove greenhouse gases

1. OSTP (1997) provides an accessible and concise introduction to the 1997 status of climate change science.

once they are emitted. But climate policy can slow down the rate at which we are changing climate, and can create greater flexibility for individual responses to climate change or greater effectiveness for individual responses by coordinating them.

This paper refers to any policy that significantly reduces emissions of greenhouse gases as "climate policy." Significant means a reduction of 300 to 800 million metric tons of carbon (defined later in the paper) per year achieved in the 2010 to 2030 timeframe. Most analyses to date have focused on the impacts of reducing carbon emissions from energy consumption via emissions taxes or a limited number of tradable emissions permits. Ultimately, climate policy will be more specific about the emissions reduction to be achieved and will include nonenergy sources of greenhouse gases (for example, land-use practices) and activities that help to remove greenhouse gases once emitted (for example, tree planting). But this less specific definition is adequate for this paper.

WHAT IS THE "KYOTO PROTOCOL" AND HOW DOES IT COMPARE WITH "CLIMATE POLICY"?

The 1992 Framework Convention on Climate Change established a procedure by which nations could work together toward control of global climate change caused by human activities. The parties to the Convention have conferred annually since 1995, a meeting referred to as a Conference of the Parties. The third Conference of the Parties (COP-3) agreed to the core elements of a proposed, legally binding treaty in Kyoto, Japan, in December of 1997. The agreed-to protocol requires an 8 percent reduction below the 1990 emission level for the European Union, a 7 percent reduction for the United States,[2] and a 6 percent reduction for Japan, to be achieved between the years 2008 and 2012.

The Kyoto Protocol is incomplete, however, in a number of important ways that the parties to the Convention are continuing to negotiate (for example, at COP-4 in Buenos Aires, Argentina, in November 1998 and COP-5 from October 25th to November 5th, 1999, in Bonn, Germany). Voluntary or binding commitments by developing countries do not yet exist, a compliance monitoring and enforcement regime has not been specified, and the rules governing cooperation in implementation across national boundaries (permit trading or investments by developed countries in developing countries) are still unclear. The Kyoto Protocol is an example of climate

2. This amounts to a reduction of 600 to 650 million metric tons of carbon emissions per year.

policy, as defined above, but like our definition, it is also lacking in many specific details.

Further, Congress will almost certainly not approve a legally binding treaty that does not go significantly beyond the protocol to address concerns raised in *Resolution 98, Expressing the Sense of the Senate Regarding the United Nations Framework Convention on Climate Change* (passed unanimously on 25 July 1997). This resolution requires further commitments from developing countries before the Senate will consider ratifying a binding international treaty that reduces U.S. greenhouse gas emissions.

II. SOME BASIC FACTS, DESPITE UNCERTAINTY

WHAT ARE "CARBON EMISSIONS" AND WHAT CAUSES THEM?

The Energy Policy Act of 1992 requires the Energy Information Administration (EIA) within the U.S. Department of Energy (DOE) to prepare an inventory of national aggregate emissions of greenhouse gases for each calendar year from 1987 forward. The gases in the inventory include carbon dioxide, methane, nitrous oxide, halocarbons, and other gases. Three gases within the last category—hydrofluorocarbons, perfluorocarbons, and sulfur hexaflouride—are strong greenhouse gases whose emissions are growing more rapidly than other GHGs.

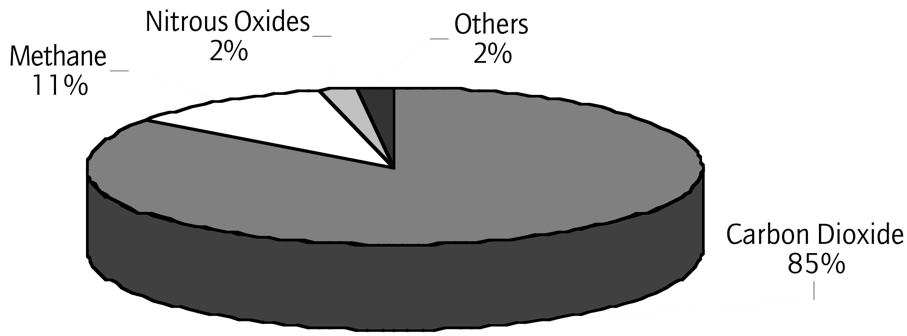
The relative contribution of each gas to the climate change problem is complex[3] and still being studied. Nonetheless, approximate global warming potentials (GWPs) have been estimated so that one can compare the impacts of various gases and the relative value of controlling their emissions. GWPs allow one to refer to greenhouse gas emissions from any source in units of "carbon equivalent." These units are what people mean when they refer to "carbon emissions."

The GWP for carbon dioxide is arbitrarily set equal to one. The estimated GWPs for other gases, over long time horizons, range from 7 for methane to 170 for nitrous oxide to as high as 34,900 for sulfur hexaflouride. This means that a ton of methane emissions has about the same climate change impact as seven tons of carbon dioxide. It also means that if it is reasonable to spend $1 per metric ton of carbon dioxide emissions abatement, it would also be reasonable to spend $34,900 per metric ton of sulfur hexaflouride abatement.

Using the GWPs, one can estimate the relative impacts of anthropogenic U.S. emissions of the various gases. Figure 1 (based on data in EIA 1997b) presents the relative warming contribution of various gases in the EIA inventory for 1996 using the 1995 IPCC GWPs for long time horizons (500 years or so).

3. Greenhouse gases have markedly different radiation absorption characteristics, atmospheric lifetimes, and interaction patterns with other chemicals in the atmosphere.

FIGURE 1: **RELATIVE CONTRIBUTION TO U.S.-INDUCED WARMING BY TYPE OF EMISSION**



Although gases other than carbon dioxide (methane, nitrous oxides, and others) are less than 1 percent of the estimated weight of annual GHG emissions in the United States, they create almost 15 percent of the carbon emissions in each year calculated using the concept of global warming potential (GWP). Nearly all carbon dioxide emissions in the United States (98.5 percent) come from combustion of fossil fuels. Therefore, although it is reasonable to focus on carbon dioxide from energy as a first, approximate description of the greenhouse gas problem, it is also true that reductions in other types of greenhouse gas emissions can play an extremely important role in controlling human-induced climate change. As will be discussed below, abatement of gases other than carbon dioxide is even more important in the 100-year time horizon than in the 500-year time horizon that is usually examined.

Sources of carbon dioxide emissions from energy use in 1996 by EIA sector are presented in table 1a. Electric utility emissions have been distributed across sectors in proportion to their use of electric power. The total of percentages in table 1a is not 100 percent; the percentages have been manipulated to sum to 98.5 percent of the 85 percent of carbon emissions attributable to carbon dioxide from energy. This allows one to see the contribution of carbon dioxide emissions from each of the EIA's energy end-use sectors to the total problem.

This table reveals the potential value of improvements in electrical production, distribution, and end-use efficiency. Carbon dioxide emissions from electric energy sources account for 30 percent of total carbon emissions, over 60 percent of the residential sector, and over 70 percent of the commercial sector.

TABLE 1A: **RELATIVE CONTRIBUTION OF CARBON DIOXIDE EMISSIONS TO U.S.-INDUCED WARMING BY EIA END-USE SECTOR, 1996**

EIA Sector	Nonelectric	Electric	Total*
Transportation	27%	0%	27%
Industrial	18%	10%	27%
Residential	6%	10%	16%
Commercial	4%	9%	13%
Total*	55%	29%	84%

* due to rounding sum of percentages may not equal 100

The transportation sector accounts for about 27 percent of U.S. carbon emissions. It is the fastest growing sector since the inventory began (1989) and will soon surpass the industrial sector as the largest current source of emissions (EIA 1997a). Nearly two-thirds of transportation emissions are from motor gasoline, revealing the potential value of technological advances in automobile design as well as the potential value of moving users into more fuel-efficient vehicles that are already available. The industrial sector also accounts for about 27 percent of total carbon emissions. It has the slowest emissions growth rate of the four sectors since 1989 due to energy-efficiency improvements and slow growth in energy-intensive industries. Energy consumption in this sector is dominated by the need for heat and power.

The contributions of GHGs other than carbon dioxide are not presented in table 1a since the EIA does not provide this data in those sectoral categories. Table 1b complements table 1a by presenting the direct contributions of methane, nitrous oxide, and the other three gases to 1996 U.S.-induced warming. We use the principal EIA categories for these gases, which are not entirely consistent across categories. Note that the total percentages in table 1b are the same as the percentages for these categories in figure 1.

This table brings forth two issues: First, claims about impacts on "industry" need to be examined carefully. For example, agriculture falls within the industrial sector for carbon dioxide emissions (table 1a), but is a separate category for methane and nitrous oxide emissions (table 1b).

Second, as mentioned previously, economic analysis based primarily on energy-related carbon dioxide abatement neglects at least 15 percent of the problem. This was justifiable when analysis of GHG abatement was in its infancy. But as analysis of these issues advances, the cost of abatement from other sources is being investigated in greater detail. For example, further breakdown of table 1b would show that methane vented from oil wells, coal mines, landfills, and animal waste impoundments, along with fugitive emissions (leaks) from gas processing plants and gate stations, account for more than three-fourths of methane emissions in 1996, or about 8 percent of U.S.-induced warming. Since energy is recoverable from reduced emissions of methane sources, the economics of abatement should be considerably different than for carbon dioxide.

TABLE 1B: **RELATIVE CONTRIBUTION TO U.S.-INDUCED WARMING OF GASES OTHER THAN CARBON DIOXIDE, 1996**

Source	Methane	Nitrous Oxide	HFCs, PFCs, and SF6	Total*
Energy	4%	1%	NA	5%
Waste	3%	NA	NA	3%
Agriculture	3%	1%	NA	4%
Industrial Processes	0%	1%	2%	3%
Total*	11%	2%	2%	15%

* due to rounding sum of percentages may not equal 100

This percentage (8 percent) is relatively small compared with some of the sources mentioned above; for example, it is less than half the contribution of motor gasoline in the transportation sector (18 percent). But it is also not trivial. In addition, the estimates in figure 1 and tables 1a and 1b are based on long-term (500-year) GWPs. The GWPs for a shorter but still lengthy timeframe (100 years) are much higher for nitrous oxide (310 versus 170) and methane (21 versus 7) due to atmospheric chemistry considerations. That is, the warming impact of these gases relative to carbon dioxide is significantly higher in the 100-year timeframe. Indeed, if the 100-year GWPs for methane and nitrous oxide are used,[4] methane would account for 25 percent of U.S.-induced warming and carbon dioxide would account for only 70

4. Which set of GWPs to use is a difficult issue. EIA reports typically use the 500-year GWPs, while a recent Clinton administration statement on climate policy (July 1998) presents the 100-year GWPs. If fairness demands we account for impacts to all future generations, the 500-year GWPs would seem to be appropriate since the GWPs do not change much for longer timeframes. If fairness demands only an accounting for the next seven generations, as in the famous saying of a Native American chief, other GWPs may be appropriate.

percent. Under this alternate assumption, the sources of methane emissions in the previous example would contribute more to U.S.-induced warming (19 percent) than motor gasoline (15 percent).

Finally, some basic information about emissions projections is useful because changes in projections are a significant source of confusion in climate policy discussions. The Kyoto Protocol requires the United States to reduce carbon emissions to 7 percent below the 1990 level by the 2008–2012 timeframe. But the total amount of abatement (in tons) and the percentage reduction required depend on the estimated growth rate of emissions. Faster estimated growth of emissions implies that abatement policy must be more vigorous if the Kyoto target is to be met. And estimated growth rates for carbon dioxide from energy emissions in the United States have been rising. This is because energy prices have been lower than anticipated and the economy has grown more rapidly than anticipated. If reality exceeds or falls below current expectations, projections will be revised yet again, perhaps significantly.

Some approximate numbers may be helpful. The Kyoto target requires that emissions be reduced to about 1,500 million metric tons of carbon equivalent. Using the 1998 EIA estimate of carbon dioxide emissions from energy in the year 2010 (about 1,800 million metric tons) and assuming that year 2010 carbon dioxide emissions from energy are 84 percent of total carbon emissions, one obtains a baseline emissions estimate of around 2,150 million metric tons. This means that abatement of 650 million metric tons of carbon equivalent might be required (2,150 minus 1,500), or about a 30 percent reduction below baseline.

But if one uses the 1997 EIA estimate of carbon dioxide emissions from energy, one finds that meeting the Kyoto target requires around 565 million metric tons of abatement, or about a 25 percent reduction below baseline. Stated another way, the increase in estimated baseline from 1997 to 1998 increased the amount of abatement estimated to be required by 15 percent (650 minus 565, then divided by 565). The amount of abatement required will depend on actual emission growth rates over the next decade or so.

ARE CURRENT CARBON EMISSIONS "EXCESSIVE"?

Yes. Elementary economics says that when a scarce good is free it will be consumed "excessively" relative to the socially desirable level. Overuse of the commons is a problem with numerous historical precedents and extensive analysis in the economics literature. There is nothing controversial about the idea that carbon emissions today are excessive relative to what would be best for American society.

Nor is the cause of excessive emissions controversial—the absence of a global market ("market failure") for such emissions.

Again, some numbers may be helpful. The natural systems of the Earth are estimated by the IPCC to be able to remove (sequester) approximately 4 billion metric tons of carbon per year. But global emissions are currently in the vicinity of 6.25 billion metric tons (gigatons) per year, and will be in the vicinity of 5.75 billion metric tons per year even if the Kyoto targets are achieved. Any climate change policy considered by Congress in the next few years will not come close to eliminating excessive, socially costly carbon emissions from American sources. It will be only one step toward formalizing our recognition as a society that the natural world has a limited capacity to absorb gaseous carbon wastes, and that efficient and equitable use of that capacity requires a variety of public policy actions.

DO THE BENEFITS OF CLIMATE POLICY EXCEED ITS COSTS?

Possibly. If not, the benefits fall short of the costs by a relatively small amount. This rather straightforward answer, despite numerous claims to the contrary, is thoroughly documented in a recent survey by Repetto and Austin (1997) and the previously mentioned discussion paper for Redefining Progress (DeCanio 1997). Repetto and Austin show that 80 percent of the variation in results among 162 estimates from 16 economic models can be explained by a relatively short set of assumptions.[5]

Using Repetto and Austin's analysis, one finds that a 40 percent reduction in carbon dioxide from energy emissions in the United States by the year 2020[6] has an impact on U.S. GDP that is approximately between a 4 percent loss and a 3 percent gain. An "average" model estimate is therefore about a 0.5 percent loss of GDP. This is consistent with the discussion in DeCanio (1997).

But using an "average" result to make policy decisions is inappropriate for at least two reasons. First, the comparison of models shows that some models have left

5. These assumptions are: a noncarbon source of energy will eventually be available at reasonable price (for example, nuclear fusion or solar), persons and businesses in the model are able to respond efficiently to climate change policy by substituting less expensive products and inputs as the relative prices of these products and inputs change, transitional inefficiencies persist, abatement policy is jointly implemented with other industrial nations, revenues raised by GHG taxes or auctioned permits are recycled into the economy in an efficient manner, and air pollution and climate change damages are averted.

6. The data in Repetto and Austin 1997 are arranged to show GDP change as a function of emissions reduction level in 2020. We have selected a 40 percent reduction in 2020 for our discussion because it crudely represents a forward projection of a 25 to 30 percent reduction by 2010, the target for the United States in the Kyoto Protocol.

out important considerations that cannot reasonably be left out. For example, including air pollution and climate change damages averted reduces the impact on U.S. GDP of a 40 percent reduction in carbon dioxide from energy emissions by 2020 by about 1.5 percent. Even if one believes that these averted damage numbers are too high, the failure to include any such numbers is not realistic. [7] Consequently, the average of credible estimates must be better than the average of all estimates.

Second, the model runs have helped us to understand how climate policy should be structured to have the greatest net value. For example, using revenues from carbon taxes or auctioned permits-to-emit in the most efficient way reduces the impact on GDP by at least 1 percent. There is broad agreement on this point among economists. Consequently, climate policies that have a realistic chance of adoption will likely collect and recycle revenues in an efficient way. Again, simple logic says that the average of the policies we might actually adopt must be better than the average of all policies that were studied.

So the best estimate of the net cost of realistic climate policy is better than the average of all estimates. Since the average estimate is a loss of about 0.5 percent of GDP, the best credible estimate is quite possibly a gain, but at worst is a small loss. This is consistent with economic theory, which says that correcting a market failure usually (but not always) increases economic efficiency (the sum of benefits less costs).

7. Numerous credible sources indicate that averted damages are significant. For example, Nordhaus (1994) provides estimates of the benefits of preventing a doubling of atmospheric carbon dioxide that range from 1.0 to 1.3 percent of U.S. GDP (his own; Cline 1992; Fankhauser 1993). Although these numbers are not directly comparable with those above, they help to demonstrate that omitting averted damages is inappropriate.

III. WHAT DO WE KNOW AT THE NATIONAL LEVEL, DESPITE UNCERTAINTY?

Climate change is imposing costs and creating benefits throughout the world and will continue to do so for hundreds of years. Some of these costs and benefits will be borne in monetary terms (for example, higher prices for some products), while others will be borne in nonmonetary terms (for example, species loss when acclimation to changed climate is not physically possible). Great scientific uncertainty about the global climate system exists, and the range of estimated economic costs and benefits of climate policy depends on highly uncertain factors such as the rate at which "clean" energy technologies will develop. Despite these uncertainties, there are some things that are certain.

First, well-designed policies to control climate change will lead to (absolutely or relatively) lower consumption of fossil fuels. This seemingly obvious point is worth emphasizing since it is often lost amidst the noise. The size of the impact is a matter of honest dispute, but the basic distributional change that is being contemplated by society is not. Significant abatement means that use of fossil fuels will contract relative to the no-policy baseline, and perhaps in absolute terms. This means that careers and investments in the fossil fuel industry will change significantly, and perhaps for the worse (although also perhaps for the better, if these industries successfully diversify). This is the primary driving force, at least to date, of the political battle that is being fought over climate change policy, including the enormous amount of publicity for the relatively few scientists who believe that climate change is not happening or is entirely due to nonhuman causes.

The underexploited technological opportunities identified in many studies (for example, DOE 1997a; Lovins and Lovins 1997) do not prevent this impact, and could exacerbate it. For example, suppose investments in electric energy conservation (for example, higher efficiency motors and lamps) reduce electric use significantly. Then the same quantity of end-use service (for example, motive power or light) will require less fossil fuel to produce, all other factors equal. Underexploited technological opportunities reduce the cost of GHG abatement (that is, substituting away from fossil fuels is less costly), but they do not alter the basic pattern of declining (relative to the baseline) fossil fuel use that is implicit in emissions abatement policy focused on carbon dioxide from energy. **Unless energy suppliers end up owning the new, formerly underexploited technology devices, their percentage share of the U.S. economy will decline.**

In the longer term (beyond 2020) there may be technological opportunities for "emissionless" energy production using fossil fuels (DOE 1997b). In the time horizon that drives the political process, however, fossil fuel suppliers have only three choices: (1) diversify, (2) contract relative to a no-policy scenario, or (3) prevent adoption of climate change policy. Some companies, such as British Petroleum (BP), Shell, and Sunoco seem to have made the first choice. Many others—including many members of the Global Climate Coalition, the leading U.S. anti–climate change policy lobbying group—seem to have chosen the third option.

Second, the policy context within which climate policy creates impacts will change over the many-decade timeframe involved. These changes may significantly alter the impacts of climate policy. This has implications for the total cost of climate policy and for our ability to estimate its distribution of impacts. For example, electricity deregulation is underway in California and seems likely to occur throughout the United States in some (perhaps limited) form. If deregulation or other policy measures can greatly reduce the price of electricity (a 10 percent reduction has already been achieved in California), then a combination of deregulation and climate policy will have a much smaller cost (or greater benefits), and a different distribution of impacts on workers and investors than is estimated at present.[8] Similarly, a study by the Alliance to Save Energy (ASE et al. 1997) combines fundamental tax reform (consumption or flat taxes) with energy taxes. They find that the combination of consumption and energy taxes increases GDP and reduces air pollution and climate change damages.

We do not argue that these examples are correct. Our point is that we can be certain that the future will not unfold as we estimate it will today. Some of the important reasons for that can be identified in a general way now (for example, electricity deregulation and the possibility of fundamental tax reform), while others will not emerge until later years. We can be reasonably certain that any real climate

8. WEFA (1998) claims to have accounted for the impact of electricity deregulation via the rate at which energy use per dollar of GDP declines over time. But their assessment of the potential for such improvements is far less than that of others (for example, Tellus Institute and Stockholm Environment Institute 1997, 1998), and deregulation has many pathways for reducing the price of electricity other than this rate. According to the Administration Economic Analysis (1998), a 10 percent decline in electricity prices nationwide is expected from restructuring. Electricity prices would not rise a cent if this is correct and restructuring were implemented along with a $46 per ton carbon emissions tax or carbon permit price.

policy will need to be adjusted significantly over a multiple-decade time horizon. This means that the most important result of "dueling models" is identification of the most important issues to be addressed along the way, rather than very accurate statements about how much climate policy will benefit or cost the nation overall, or groups of workers or investors in particular.

IV. WHAT DO WE KNOW AT THE INDUSTRIAL-SECTOR LEVEL, DESPITE UNCERTAINTY?

In an ideal paper we would compare the estimated impacts on groups of workers and investors from a range of models applied to a range of policies. Unfortunately, impact data of this type does not exist. Analysis of the economic impacts of policies to reduce energy-related carbon dioxide emissions began more than a decade ago. Researchers have examined different policy scenarios using a wide variety of models, many of which were initially created for other purposes.

Furthermore, various approaches involve use of different types and vintages of data, leading to a variety of ways of categorizing business activity into "industry" categories. For example, the results in WEFA (1998) are in 7 to 9 categories; the Goulder model (1994) has 17 categories of final consumer goods and 13 industries that produce the energy and materials that go into these 17 final goods; the Jorgenson-Wilcoxen model (Jorgenson et al. 1992; Norland and Ninassi 1998) has 35 categories; and CRA–DRI/McGraw-Hill (1994) has 105 categories.

Even if the categories were standardized, most models use a single wage rate for all workers, a single interest rate for all investments, and substitution parameters (say, between capital and labor in each industrial sector) that may differ widely among the models.[9] And many of the models assume full employment, which is why one cannot directly estimate the number of displaced workers. This renders the results even less useful for our purpose, which is to compare the impact of various climate policies on wages and investment returns in different business sectors, and to discuss how many current workers in each sector might actually lose their jobs.

9. The ability of various categories of businesses to substitute away from energy and toward labor or capital if energy prices rise is critical to the estimated impacts on workers and investors in these categories. Not only do estimates of these substitution possibilities differ, but one can argue that substitution data from past times when energy prices rose is not of much relevance to the future, given the technology that has been developed but not implemented as fossil fuel prices fell in the last decade. Furthermore, the substitution possibilities for direct energy use are less important than the substitution possibilities for indirect energy use (energy embodied in all inputs to a process, not just energy used directly). Patterns of indirect energy use are very different from patterns of direct energy use (for example, Norris 1998).

Consequently, tabular comparison of model results is neither feasible nor useful. The following questions discuss the three main types of possible policy impacts on workers and investors—displaced workers, lower growth in real wages, and lower returns on investment—citing various model results as appropriate.

WILL CLIMATE CHANGE OR CLIMATE POLICY CAUSE LAY-OFFS?

Some, but not many. A recent study funded by the American Petroleum Institute (WEFA 1998) claims that 2.4 million jobs would be lost if the United States were to adopt the Kyoto Protocol. Nearly every economic sector in all 50 states loses jobs compared to a projection of future employment growth. This number is not credible for numerous reasons,[10] but is useful for comparison with another type of number—the number of *displaced* workers that climate policy is estimated to cause.

Although slower job growth may mean fewer raises, fewer promotional opportunities, or a more difficult time for young workers entering the workforce, it does not necessarily translate into job losses by existing workers. Indeed, a reduction in a positive rate of job growth does not necessarily imply any displaced workers. What is critical is whether the reduction is sufficient to cause a negative rate of job growth, which does imply displaced workers.

Another model (Charles River Associates and DRI/McGraw-Hill 1994), which contains "pessimistic" assumptions similar to those in the American Petroleum Institute–funded study, estimates that less than 0.13 percent of the labor force (roughly 150,000 jobs) will be displaced by a $200 per ton carbon tax and less than 0.04 percent of the labor force (roughly 50,000 jobs) will be displaced by a $100 per ton carbon tax. The study, prepared for the Electric Power Research Institute (EPRI), traces the impacts of carbon taxes on 105 industry types. Its results are based on three tax scenarios—$50, $100, and $200 per metric ton of carbon—by the year 2010. According to the study, reducing emissions to 1990 levels by the target date will require tax levels between $100 and $200.

Bernstein and Montgomery (1998) report that a tax of $295 per ton will be required to reduce emissions 7 percent below the 1990 levels by 2010 (the Kyoto target for the United States). Extrapolating the 1994 estimates upward to account for this more aggressive policy yields roughly 300,000 displaced jobs, or about one-fourth of

10. The study contains worst-case assumptions for all eight critical items identified in Repetto and Austin (1997). The most significant flaw is that the policy that is modeled is not proposed by anyone, nor will it be because it contains many inefficient and undesirable elements.

one percent of the workforce. If each displaced worker were provided with $200,000 of retraining and relocation assistance, a one-time expense of $60 billion would result. But this expense, if amortized over 30 years at 7 percent, amounts to less than 20 percent of the annual revenue associated with a $295 per ton tax.[11] Although the absolute fiscal impacts involved in climate change policies may appear large, these fiscal impacts are much smaller when viewed in the timeframe over which climate policies will be implemented, and their benefits realized.

The 1994 estimate by CRA and DRI/McGraw-Hill of the displaced jobs by industry is presented in table 2. The $100 per metric ton tax displaces workers in only five of the one hundred five industries in the first time period in the model that is affected by the policy (the year 2000), and displaced workers in only four industries in the years 2005 or 2010. The five industries are coal mining, crude petroleum and natural gas, ordnance, petroleum refining, and gas utilities. The $200 per metric ton tax increases the number of industries with displaced workers to seven (the previous five, plus new construction and electric utilities) in the year 2000, six in 2005, and five in 2010.

Table 2 also reinforces the point made previously: The primary distributional impact of climate policy is to decrease the relative (and perhaps absolute) size of fossil fuel suppliers within the U.S. economy. Sectors such as electric utilities and construction have fewer displaced workers over time as they adjust away from dependence on fossil fuels. This is the case even though the economy is estimated to contract significantly, in aggregate, in this model. In contrast, sectors such as coal mining, crude petroleum and natural gas, and gas utilities experience more displaced workers over time as the economy adjusts away from reliance on these sectors.

The WEFA and CRA–DRI/McGraw-Hill studies are representative of those that conclude that climate policy will be very costly to the American economy overall. At the other extreme, however, some models estimate that no workers will be displaced and that a small increase in the number of jobs (compared to a baseline) will occur. For example, the study *Energy Innovations* (ASE et al. 1997) estimates an increase of about 770,000 jobs by the year 2010 relative to a baseline projection. One plausible reason for this result is the belief that research and development and technological change are underinvested in by market economies because the benefits cannot be captured entirely by those who invest (see DeCanio 1997 for an interesting

11. The current national debt is around $5.5 trillion. This additional $60 billion would increase national debt by about 1 percent. But unlike the current debt, which is not being paid down, debt of this sort would be retired in 30 years. After that, carbon tax or permit revenues could be used for other purposes.

discussion). This means that technological change can be accelerated by government policy, and doing so is good for the economy rather than bad. Another plausible reason for the result is that nonfossil forms of energy are more labor intensive than fossil energy, so substitution toward them may create more jobs than it costs.

TABLE 2: **ESTIMATE OF DISPLACED WORKERS (from CRA and DRI/McGraw-Hill 1994)**

Industry	Workers Displaced (thousands)					
	$100 tax			$200 tax		
	2000	2005	2010	2000	2005	2010
Coal Mining	3	3	1	13	19	24
Crude Petroleum and Natural Gas	19	27	34	23	34	43
New Construction	0	0	0	35	0	0
Ordnance	19	15	8	19	16	10
Petroleum Refining	2	3	3	3	7	7
Electric Utilities	0	0	0	30	18	0
Gas Utilities	6	0	0	30	40	44
Total	49	48	46	153	134	128

The baseline projection of future employment in all of these models, however, does not include job losses due to climate change. Consequently, real climate policy must guard against the "fallacy of misplaced concreteness." For example, a recent severe freeze in California is predicted to cost 14,000 migrant workers their jobs this harvest season, not to mention the impact on jobs in the downstream industries affected by the freeze (for example, processing or trucking). Similarly, how many work-hours, profits, and subsequent jobs were lost due to the unusual icestorms in Maine and Quebec in late 1998? It is quite difficult to know which "natural" disasters are truly natural, and which are partially caused by climate change. Consequently, comparing employment with climate change versus employment with climate policy that partially controls climate change is quite difficult, and is rarely done. We do not know with any accuracy how many workers will be displaced or how many more or fewer jobs will be created by climate policy of various kinds, in comparison with uncontrolled climate change.

WILL CLIMATE CHANGE OR CLIMATE POLICY LOWER REAL WAGES?

Probably not for most workers. Since climate policy will be phased in over many years, reductions in the rate of wage growth may occur, but this is not the same as an absolute reduction in real wages. Consequently, although models that estimate a contraction in GDP relative to a baseline also estimate a contraction in real wage growth relative to a baseline, we have not found any model[12] that estimates that the future, average wage will be lower in real dollars than the average wage that exists today. Even the most pessimistic model in our survey (WEFA 1998) estimates that real GDP per capita and per employee will rise from $25,600 and $54,000, respectively, in 1995, to $30,200 and $61,000, respectively, in 2010, despite limiting carbon emissions to 93 percent of 1990 levels.

Lower growth of real wages, however, could be quite difficult for some workers. Much attention has been paid to the differential in rate of growth of income between upper- and lower-income groups in the United States over the last few decades. Part of this difference comes from rising wages for more highly trained workers and flat or declining wages for those that are less well educated or skilled. Ideally, we would consider the impact of climate change and climate policy on real wages by sector of the economy or by income category. Unfortunately, most models include only a single wage for the entire economy. This is both because labor markets are usually assumed to be competitive, with workers who are paid less moving into sectors that pay more until wages in all sectors have equalized, and because models with numerous wage rates are computationally complex and require data that is often not available.

It is certainly possible, even plausible, that real wages will actually decline in some sectors of the economy. But the modeling exercises to date have not directly addressed this issue, so little can be said quantitatively about which workers will experience this problem, if any. Qualitatively, we can say that coal miners and petroleum workers will probably be hurt, and workers who have the skills to help transform the economy from a fossil fuel to a renewable energy base will probably benefit.

For the many sectors that are less clearly linked to this economic transition, the impact on real wages will reflect changes in the growth rate of labor productivity. Productivity growth overall can come from better worker education, from on-job

12. Models reviewed include Bernstein and Montgomery (1998), CRA–DRI/McGraw-Hill (1994), WEFA (1998), the Second Generation Model (Edmonds et al. 1997), Goulder (1994), the Jorgenson-Wilcoxen model (Jorgenson et al. 1992; Norland and Ninassi 1998), the G-cubed model (McKibbin and Wilcoxen 1992, 1995), input-output analysis by Hoerner (1997, Forthcoming), and a model by Boyd-Krutilla-Viscusi (1995).

training and learning by doing, from more capital stock per worker, from technological innovations, and from other sources. For example, construction workers with power machinery (and the energy to run that machinery), will be more productive than those forced to work solely with hand tools. Rises in the price of energy, all other things equal, will reduce the productivity of construction workers who routinely employ power tools. But the long-term growth rate of the real wage, in theory, reflects the change in labor productivity after productivity changes from improvements in other factors of production have been accounted for. For example, a new machine may increase the amount of a product (or its quality) created by a worker in an hour of work, but the value of the increase in output will theoretically be paid to the inventor of the new machine or the investor in it. In the long-term, real wages increase if and only if workers become "smarter" and more capable.

There is nothing about climate change or climate policy that will make workers less capable, although in the short term, climate change or policy can reduce the average amount of product each worker produces in an hour. If energy prices, on average, rise from climate policy, some short-term impacts on wages will occur (economists call these transitional effects or transitional inefficiencies). But such impacts occur nearly continuously in advanced economies, from causes as varied as regulation, adoption of new technology, changes in management philosophy, and so forth. And climate change itself has and will continue to create transitional inefficiencies in production, exerting downward pressure on real wages. Climate change may cause inclement or unexpected weather, power outages, stranded vehicles or workers, supplies delayed because a train or truck can't cross a swollen river, or numerous other problems that affect profitability and, ultimately, wages.

In the long run, real wages will rise if we continue to overcome transitional inefficiencies—that is, if we empower workers to learn to produce value faster than obstacles that make it hard to produce value are placed in their way. This is true for the economy overall and by sector. Economic logic says, qualitatively, that the workers whose wages will be hardest hit by climate change or policy in the long run will be those who have the least individual skill (human capital), or who work in organizations with limited capability or incentive to invest in their workers. One of the "fairest" things climate policy could do would be to make investment in human capital (people skills) more financially attractive in sectors that may be hard hit by climate change or policy.

WILL CLIMATE CHANGE OR CLIMATE POLICY REDUCE RETURNS ON INVESTMENTS?

On some investments, yes; on others, no. The return on fossil fuel assets (for example, oil or coal in the ground) will decline. Suppose you invest one dollar in coal today with the expectation that it will sell next year for $1.07 (after all other expenses are paid). Then your expected rate of return is 7 percent. If during the coming year the government unexpectedly imposes a five cent tax on your coal, your rate of return will decline to 2 percent unless consumers are willing to pay more for it (that is, you can pass some of the tax on to them). As noted previously, this is an economic effect of climate policy we can be sure of in the long run, although natural gas assets, for example, might rise in value in the short term since they will be relatively attractive compared with coal or oil.

On the other hand, the rate of return on reproducible assets (for example, structures and plant equipment) may rise or fall, depending on how interest rates change in response to climate policy, and other complications. Interestingly, a higher interest rate (usually seen as an undesirable macroeconomic impact) implies an increase in the rate of return to reproducible assets. Suppose you can earn $0.07 per year from ownership of a $1 machine after all other expenses are paid, and you could also earn this much from a savings account. Then your expected return on investment is 7 percent. Suppose the interest rate rises in the next year. Then you and others who might invest in more of this type of machine (or in replacing the machines that have worn out that year) can do better by leaving their money in savings accounts. This means there are fewer machines available than would have been the case (investment in machines has contracted relative to a baseline). But this means that the services your old machine provides are now relatively scarcer, and therefore worth more. The rate of return on your old machine will rise. This example differs from the coal example because the producer price of coal (the price received by the coal investor) has fallen due to climate policy, but the producer price of machine services (the price received by owners of existing machines) has risen.

Many real-world complications have been left out of the machine example. But there is good reason to believe that the example is approximately correct. Economic theory says that old capital goods will rise in value when new capital goods become more expensive (just as used car prices rise when new car prices rise). CRA and DRI/McGraw-Hill (1994) examined this question by looking at the change in value of

30 types of reproducible assets[13] if a carbon tax were imposed. They found an average increase in the value of reproducible capital assets in the U.S. economy (above a baseline) of 1.3 percent. All 30 categories of such assets increase in value, with a range from 0.1 percent to 3.6 percent. Some representative figures from their work are summarized in table 3.

TABLE 3: **ESTIMATED CHANGE IN CAPITAL ASSET VALUES FROM A CARBON TAX**

Equipment	% Change	Structures	% Change
Autos	+0.70	Public Utilities	+1.67
Computers	+1.23	Buildings and Other Structures	+1.21
Fabricated Metals	+2.18		
General Industrial Machinery	+2.06		
Buses, Trucks, and Trailers	+2.20		
Aircraft	+0.53		
Mining and Oilfield	+3.60		
Tractors	+2.08		
Agricultural	+1.77		
Construction	+2.01		

The net effect of changes in asset values and rates of return on any particular investment will depend on the blend of assets that underlie the investment.[14] For example, an electric utility may own hydroelectric, nuclear, fossil fuel, and renewable-energy power plants, and they may own fossil fuels in the ground. The change in the rate of return to an owner of stock in some particular utility company will be difficult to calculate. The largest negative impacts will occur when a company

13. An asset increases in value when its rate of return increases. CRA–DRI/McGraw-Hill do not describe the rate of return associated with the changes in asset values in table 3; hence we simply report change in asset value.

14. Boyd, Krutilla, and Viscusi (1995) suggest that the value of capital will decline in response to a carbon tax. But they do not distinguish between equipment and structures and the types of land in their model, so perhaps the decline in value of some categories of assets offsets a rise in the value of other categories of assets. Alternately, climate policy may cause interest rates to decline in their model; in which case all types of existing assets would become less valuable, but investment would be stimulated.

is not diversified, and owns primarily fossil fuels reserves and the core infrastructure (mines, pipelines, etc.) needed to extract it and transport it to buyers. Although climate policy might cause these infrastructure assets to rise in value (see mining and oilfield equipment in table 3), such assets might also decline in value, at least over time. [15]

In summary, investors in undiversified suppliers of fossil fuels will almost certainly experience lower rates of return and asset values. Investors in old capital goods may experience increases or decreases in the rate of return or the value of their assets, depending in large part on the changes in interest rates in the economy caused by climate policy. Notably, investors in old machines and equipment may benefit from rises in interest rates that are negative impacts for the economy as a whole.

In addition, some changes will be transitional in nature, others much longer term. For example, natural gas will likely be more valuable in the short term since it is the least carbon-intensive fossil fuel, but less valuable in the long term if nonfossil energy sources dominate the energy marketplace. Impacts on investors of publicly traded stocks may be identifiable in a much shorter timeframe than will be required to identify impacts on workers. This is because (assuming capital markets respond efficiently to changes in the natural or policy environment) the largest impacts on investors will occur when investors come to believe that climate policy will be adopted. Forward-looking investors will, in theory, adjust to any policy change at the time it is announced, in anticipation of cash-flow and other types of impacts on businesses.

15. This rise in value is probably also a transitional effect. Economic logic suggests that the permanent, long-term effect will be a decline in the value of mining and oilfield equipment.

V. FAIRNESS AND ADOPTION OF CLIMATE POLICY

Economists distinguish between descriptive (or positive) economics and normative (or welfare) economics. Although value judgements and subjective opinions are necessary to construct a model with which to estimate impacts of a policy, the output of the model is nonetheless an attempt to be descriptive. Whether society should compensate workers who lose their jobs or suffer reduced real wages because of climate policy is a normative question, however, that no amount of modeling can answer.

As has been discussed, descriptive analysis of the impacts of climate change policy on economic sectors is no simple matter even at the national level. Distributional analysis that identifies the impacts of climate change or policy on different generations (or age cohorts) of workers and investors is also difficult. Nonetheless, we believe that fairness to future generations requires that we begin to put climate policy into action as soon as possible, even though we have little reliable information about the distribution of impacts between generations. The rationale for this belief is presented below.

CAN AMERICANS AGREE ABOUT FAIRNESS?

The number of opinions about fairness in any group is almost certainly larger than the number of people in the group. Some view fairness as protection of those who are less well-off, whether due to physical infirmities, age, low income, or other reason. Others view fairness as a matter of sharing burdens equally, or avoiding disproportionate impacts on any particular group. Two classic attitudes about fairness—the outcome and process perspectives[16]—bump into each other in the following story.

16. Viewpoints on equity can be categorized in various ways. One way that is useful for the climate change debate is to contrast two polar concepts of equity. The first is that outcomes are all that matter; the second is that processes are all that matter. Many writers refer to the outcome perspective as "consequentialist" since within it one is concerned about consequences. Under this perspective one estimates the outcomes of a policy and then discusses whether those outcomes are fair or not. Were the poor

Two boys are playing and become hungry. One takes an apple and a penknife from his pocket, cuts the apple into two pieces, and allows the second boy to choose one piece. When the second boy chooses the larger piece the first boy is outraged. The second boy asks, "Would you have taken the smaller piece?" The first boy replies, "Yes, that is the polite thing to do." The second boy replies, "Then I don't see what the problem is, since you have the piece you would have taken." The second boy is focused on outcome, and sees no problem since the outcome is that which the first boy said he would have chosen. But the first boy is not concerned about the outcome, but about the values expressed in the process of choosing a piece.

One can present arguments in support of each boy's position. Indeed, philosophers have been doing so for thousands of years. But amidst these arguments there is one perspective that most Americans seem to agree with. It is that individuals are responsible for the consequences of their own actions. This principle of individual responsibility is of course not an "objective" one. It has been rejected by many societies historically and continues to be rejected by others today. But most Americans view individual responsibility as a cornerstone of our political and legal system and way of life.

IS FAILURE TO CONTROL CLIMATE CHANGE (THAT IS, ADOPT CLIMATE POLICY) UNFAIR?

Yes. Natural climate change is neither fair nor unfair. But human-induced climate change results from failure to pay the full price of various activities. Of course one cannot prove that anything is unfair. But if one believes, as most

unduly burdened? Did someone lose their job? Did those who were induced to invest by one policy (or tax) regime find their investment stranded? The process perspective is quite different. Most American citizens have little sympathy for those who are poor or unhappy but have opportunities to be otherwise. Personal responsibility and individual liberty involve the possibility that one will fail through one's own fault. (Perhaps one of the deepest tenets of our society is that we believe few people will fail in these ways, permanently, if equality of opportunity exists.) In many instances we view a negative outcome as just and fair: "They got what they deserved." Indeed, the process perspective, at its most extreme, says that society need not judge whether a policy outcome is good or bad for individuals. Fairness depends on our following a democratic process (or failing to follow it). So long as the rights of citizens are not violated, individual outcomes need not be considered. This is one basis for the widely accepted principle that Congress need not compensate "losers" for the impacts of policy decisions. Mixed perspectives also exist—indeed, most reasonable perspectives involve aspects of both. The process of making laws through representative democracy is limited in some ultimate sense by the value of the outcomes it produces. We may "throw the bums out" or reduce the size of government entirely if we feel the outcome produced is not worth the cost of the process involved. Conservatives are vigorous on this point, arguing that the benefits of government and collective action are not unlimited, but must be subject to some sort of cost-benefit analysis.

Americans seem to, that it is unfair to knowingly refuse to take responsibility for the consequences of one's actions, then failure to adopt climate policy is unfair.

The casual American observer of the international climate policy negotiations is likely mystified by the larger emissions reduction burden placed, initially, on industrialized countries. But this is directly a result of international consensus about what is fair. Most historical emissions have been the result of economic activity in industrialized nations, but the "external" cost of these emissions is being borne by everyone on the Earth, including people in poor countries who do not enjoy the benefits of industrial civilization. Citizens of island or low-lying nations are paying some of the expenses that we or our ancestors unknowingly failed to pay. That is one reason the Kyoto Protocol places *initial* responsibility for reducing emissions on industrialized countries.

Similarly, future generations will bear some of the costs of our current and past emissions of carbon. Future workers and investors in the United States will bear some of our "external" costs; that is, pay some of the price that current workers and investors would pay for fossil fuel energy if markets were complete. They will pay these external costs in various ways, such as health impacts or the hard-to-identify costs of adjustment to changing climate.

This is unfair. Suppose someone changes their land in such a way that the next rainstorm floods your house? So long as causality can be established, any court would force the perpetrator to compensate you. But climate change is different only in that the causal chain is complex and plays out over a very long time scale. My grandchildren will never be able to identify who, specifically, flooded their land (or froze out their Florida oranges,[17] or overheated their summer day in Texas). But that inability does not make what we are doing fair. If future generations could sue in court (and establish causality), we would likely lose. Common sense says that the "fair thing" is to take responsibility for the consequences of our actions.

17. A recent unexpected freeze in California was estimated to cause $600 million of damage to citrus crops. This was the second 100-year freeze in the last ten years. Recently, such stories abound.

VI. IS TAKING THE FAIR ACTION (THAT IS, CONTROLLING CLIMATE CHANGE VIA POLICY) AFFORDABLE?

As discussed previously, the best estimate of the net benefit (or cost) of climate policy is a small gain or loss of GDP. Suppose, contrary to the discussion above, that the loss is 1 percent of GDP. This is a nice round number that DeCanio (1997) has put into perspective. Although it amounts to about $70 billion,[18] DeCanio points out that it is less than six months of conservatively estimated growth of the U.S. economy (that is, one-half of a 2 percent annual rate of growth in real GDP per capita). If the costs and benefits of policy were distributed absolutely equally across all households in the United States,[19] this amounts to deferring one's next raise for six months, then continuing on with life as usual. What parent or grandparent has not done something like this already for their child or grandchild? What nation would not do this to avert a very significant, credible threat to the well-being of its future citizens?

As discussed earlier, however, the actual cost of climate policy is more likely to be in the range of a 0.5 percent loss of GDP to a small gain. And the uncertainty in the estimate does not affect this conclusion. Even the worst-case estimate of a 4 percent loss of GDP by 2020 amounts to a reduction in the growth rate of around 0.2 percent per year (about one-tenth of the annual growth in real GDP per capita), when the two decades over which policies would be phased in are taken into account. Climate policy is not only fair, but it is affordable.

18. There are, of course, other ways to calculate the costs. For example, the net present value of the loss of 1 percent of U.S. GDP is an even larger absolute number (dollars). But numbers can clarify or mislead, and DeCanio's analysis clarifies that no matter how we arrange the numbers, the net cost is likely to be less than 6 months of "holding even" in income terms, as opposed to six months of rising GDP.

19. Of course, the benefits and costs of climate change and policy are not equally distributed, so fear that one will be forced to pay disproportionately is a real political obstacle that must be overcome. Hence our recommendation for a generously funded climate change and climate policy compensation system.

FAIRNESS, REVENUE-RAISING POLICIES, AND NON-REVENUE-RAISING POLICIES

No matter what mechanism is chosen to reduce carbon emissions—regulations, taxes, or tradeable permits—prices of fossil fuels and fossil-fuel dependent products will rise.[20] This extra cashflow will pass into the hands of producers unless the chosen mechanism is a carbon tax or permits that are sold. These latter two types of policies are sometimes referred to as "revenue-raising policies," in contrast to "non-revenue-raising policies" like regulations and permit giveaways. Goulder et al. (1997) show that revenue-raising policies are more economically efficient, since the revenues can be used to reduce other taxes in the economy.

The policies that do not raise revenue are also unfair if one believes in the individual responsibility standard for fairness. Recognition that climate policy is a situation in which the fair action is also the economically efficient action might greatly help to move climate policy forward in the United States.

HOW MUCH REVENUE IS AT STAKE?

The Tellus Institute and the Stockholm Environment Institute (1997, 1998; UCS and Tellus 1998) have examined a policy package that includes tax incentives and various regulations (for example, a renewable energy percentage mandated for some electric utilities) as well as auctioned permits. Their policy package is estimated to reduce U.S. emissions by 593 million tons per year in 2010. This is about what is required under the Kyoto Protocol. The marginal cost of abatement in their estimate—the price at which permits would trade—is $56 per metric ton. And emissions of carbon from U.S. energy sources in 2010, if the Kyoto target were met, will be approximately 1,150 million metric tons per year. A favorable policy analysis therefore implies permit auction revenues would be about $65 billion in 2010, and more in earlier years.

By comparison, WEFA (1998) and Bernstein and Montgomery (1998) estimate the permit price to achieve the Kyoto target at $265 and $295 per metric ton, respectively. These unfavorable analyses yield year 2010 revenues of about $300 billion and $350 billion, respectively. Note that the larger estimates of revenue stream are associated with larger estimated costs to the economy. This means that more money will

20. There is one exception to this: tax and rebate systems where the rebate is used to subsidize output. When revenue is used to subsidize output directly, the price of output is lowered. Output-based permit allocation systems are equivalent to this type of tax and rebate system.

automatically be available under revenue-raising policies when there is more economic pain to soothe.

Several analyses (for example, Administration Economic Analysis 1998) suggest that permits may trade for less than $56 per metric ton. In particular, joint implementation with other countries may create opportunities for low-cost abatement of emissions. Bernstein and Montgomery (1998) estimate that a full global trading system would lead to a permit price of $23 per metric ton. Their analysis suggests that 82 percent of the U.S. reduction in emissions required to meet the Kyoto target would be achieved by purchasing permits from outside the United States (that is, by investing in emissions abatement outside the United States, creating "room" for more emissions within the United States).[21] At $23 per ton, annual revenues would never be less than about $27 billion per year.

Consequently, $30 to $300 billion or so per year is the revenue stream one might use as the basis for specific compensation commitments (for example, displaced workers) or social investments (for example, subsidies to support retooling or research into new technology).

IS THIS REVENUE STREAM ENOUGH TO COMPENSATE WORKERS AND INVESTORS?

Yes. As discussed below, the sum of *maximum* estimated annual costs of compensation for workers and investors amounts to about two-thirds of the estimated annual revenue stream.

In this section we discuss the maximum estimated cost of compensation for three politically important impacts of climate policy, under "optimistic" and "pessimistic" assumptions (table 4). These impacts are displaced workers, absolute decreases in real wages, and reductions in the value of nonreproducible assets like coal in the ground. We do not say that impacts should be compensated—only what it might cost to compensate for them. The ballpark impacts of climate policy are presented in billions of dollars per year and as percentages of the revenues that would be generated by efficient climate policy (that is, carbon tax or permit auction revenues). Two of the three impacts are one-time costs, so they are amortized at 7 percent over 30 years.

21. Investing in abatement outside the United States may be unfair or costly to those groups in the United States that are most susceptible to the health impacts (for example, asthma) of other emissions from fossil fuel use (like sulfur oxides). By reducing fossil fuel use outside rather than inside the United States, we deprive these groups of the "health co-benefits" of reduced local fossil fuel use. And from an efficiency perspective, investment in foreign abatement is less attractive when co-benefits are accounted for.

Favorable analyses of job impacts do not usually discuss displaced workers. The lowest estimate of displaced workers is zero. But even if climate policy creates more jobs than it costs, some workers may be displaced. Using the lowest estimate provided by CRA and DRI/McGraw-Hill (1994), and assuming a lump-sum payment[22] to each worker of $200,000, $10 billion would be required to keep displaced workers "whole." If amortized by the U.S. government over 30 years at 7 percent (that is, by sale of 30-year treasury notes), the annual expense is less than $1 billion. This amounts to less than 3 percent of the $30 billion lower-end revenue estimate. Repeating the calculation for 300,000 displaced workers under unfavorable assumptions amounts to less than 2 percent of the revenue associated with those assumptions.

TABLE 4: **MAXIMUM ESTIMATED IMPACTS ON WORKERS AND INVESTORS**

Type of Impact	**Range of Maximum Estimated Impacts**	**Approximate Annual Cost (billions)**	**Approximate Annual Cost (percent of estimated annual revenue in 2010)**
Displaced Workers	50,000 to 300,000	$1 to $6	2 to 3%
Decline in Real Income	1 to 14% Price Rise	$7 to $95	23 to 32%
Investor Loss Due to Decline in Market Value of Assets "in the Ground"	5 to 50% Decline in the Market Value of U.S. Energy Companies	$5 to $90	17 to 30%
Total Potential Cost	Not Applicable	$13 to $191	43 to 64%

Absolute declines in real wages is another impact that some believe should be compensated. That is, although the average American household is estimated to experience only a slower rate of growth of real wages, some households might experience an actual decline in real wages. The lowest two quintiles of U.S. households (lowest 40 percent of households ranked by annual income) have experienced stagnant wages for nearly three decades. Assuming that real wages for

22. Or an equivalent cost for retraining and relocation assistance. Our point here is that even if displaced workers were simply handed a large check, annual compensation cost is small relative to annual revenue.

these households remain stagnant for next 30 years, and that about 1 percent[23] more income is required to offset the price rise these incomes experience, annual payments of about $7 billion would be required to provide complete compensation. This is about 23 percent of the lower annual revenue estimate of $30 billion.

WEFA (1998) has estimated a "pessimistic" or unfavorable price rise of around 14 percent, cumulative, by the year 2010 if the Kyoto emissions reductions are to be achieved. This translates into about $95 billion per year of compensation to maintain the real purchasing power of the lower 40 percent of American households, again assuming that real wages continue to be stagnant for these households. Although the absolute compensation required is 14 times as high as with a 1 percent price rise, it still amounts to only 32 percent of the annual revenue estimate consistent with this price rise ($300 billion or more).

Investors may also experience significant impacts from climate policy that some people believe should be compensated. The most substantial impact will be the loss of value of fossil fuel assets (nonreproducible assets) as relative demand for this type of energy declines. The Congressional Budget Office (1990) for example, estimated the decline in oil, natural gas, and coal consumption from a $100 per ton carbon tax at –3, –4, and –13 percent, respectively. WEFA (1998) estimated changes in petroleum, natural gas, and coal consumption by the year 2010 from a $295 per ton carbon permit price at –9, +1, and –37 percent, respectively. Edmonds et al. (1997) estimate changes in petroleum, natural gas, and coal consumption by the year 2010 from a $108 per ton permit price at –7, +4, and –57 percent, respectively. Natural gas consumption in the latter two estimates increases during a transitional period as the economy shifts toward it from petroleum and coal.

23. This figure is consistent with the more favorable analyses of the impacts of climate policy, although those analyses do not discuss the policy's attendant price rise. However, Hoerner (1997) estimates the potential burden on manufacturing industries of a $50 per metric ton carbon tax on carbon dioxide from energy emissions. Revenue from the carbon tax is recycled via a reduction in the payroll tax. Tax burden in each SIC code examined is calculated as 100 percent of the tax on fuels consumed less 100 percent of the reduced payroll tax paid. This type of approximation (sometimes referred to as a fixed coefficient input-output method) is not uncommon in distributional analysis. Using this approach, the manufacturing sector experiences a net tax burden that is equal to 0.59 percent of the value of manufacturing shipments.

If the entire tax burden is passed on to consumers and if manufacturing were typical of the economy (actually it is more energy intensive), this implies a price rise, on average, of 0.59 percent. Lower-income households, however, spend relatively more of their income on necessities (such as energy), so the price rise they experience would be higher. Poterba (1991) estimated that the impact of a carbon tax (expressed as a percent of expenditures) on the lowest income decile of households would be about 1.65 times the impact on households in the highest income decile. Hamilton and Cameron (1994) obtained similar results. So a "favorable," but reasonable, estimate of the price rise lower-income households might face is about 1 percent (0.59 multiplied by 1.65).

It is difficult to know how changes of this magnitude will affect the price that owners of fossil fuels receive, or the stock market value of companies that own fossil fuel reserves. We are not aware of any credible analysis of this issue. But even the more pessimistic studies (like WEFA 1998) estimate that compliance with the Kyoto target for the United States (7 percent below the 1990 emission level) would cause an 11 percent decline in the refiners'acquisition cost for petroleum (what sellers of unrefined oil receive), a 5 percent increase in the natural gas well-head price, and a 22 percent decline in the coal mine-mouth price in the year 2010. If the value of U.S. energy company operations in each of these three areas were to change by the estimated percentages (if a 1 percent drop in producer price were to mean a 1 percent drop in net income), a 3 percent decline in the value of U.S. energy companies would occur.

If coal operations became entirely unprofitable, there might be only a 1 percent decline in the value of U.S. energy companies since net income from coal operations is about 1 percent of net income for U.S. energy companies. Similarly, if oil and coal operations were to become entirely unprofitable, there would probably be less than a 50 percent decline in the value of U.S. energy companies because net income from oil and coal operations is less than 50 percent of total net income. So table 4 presents a range of devaluation of U.S. energy companies (current value of about $1.8 trillion)[24] of 3 to 50 percent. As implausible as the upper end of the range is (it is hard to conceive that petroleum operations will be entirely unprofitable, after adjustments occur), it amounts to only 30 percent of the revenues associated with the more pessimistic model results. [25]

SHOULD WE COMPENSATE FOR EVERY IMPACT?

No. Governments do not compensate citizens for every impact of every policy that they adopt. There are many reasons for this, not the least of which is that doing so is often impractical and expensive. Another is that since many policies are

24. The financial reporting system (FRS) companies monitored by the Energy Information Administration (EIA 1999) had a stock market capitalization of about $900 billion on August 11, 1999 (Citibank 1999). The EIA (1999) reports that FRS companies account for approximately 50 percent of energy operations in the United States. Hence the value of U.S. energy companies is in the vicinity of $1.8 trillion.

25. This is why carbon permit giveaways, as proposed by the Environmental Defense Fund and others, is probably far more than is required to offset political opposition by investors in energy companies.

adopted, one can reasonably argue that losers from some policy are winners from another and compensation is not necessary or appropriate.

On the other hand, compensation or modifications in a policy to reduce impacts on selected groups are often built into policies as they proceed through the legislative process. There are several widely supported rationales for compensation or special provisions in policy design. One is that some groups—those with low or fixed incomes or with disabilities or special needs—are not capable of paying for certain policies, and should be sheltered from negative impacts (which may be thought of as implicit payments). This rationale is consistent with the notion of "ability to pay" that underlies the progressivity of U.S. and many state income taxes.

Our national commitment to help those who have lost significantly due to natural disaster depends on another rationale: that natural disaster can happen to anyone. Providing social insurance against natural disaster—getting those who are burdened through no fault of their own back on their feet—is in our self-interest. Most workers in the fossil fuel industry could not have known when they entered the industry that fossil fuels would cause climate change. They may be willing to change jobs, or even to relocate, so that the national problem can be solved, but they have usually asked for assistance in doing so. This is the idea behind the "Just Transition" requested in AFL-CIO environmental policy, and first put forward by leaders of the Oil, Chemical, and Atomic Workers Union (Moberg 1999).

Another rationale is that some parties have already contributed "enough" to a solution. For example, manufacturers of chlorofluorocarbons (CFCs) voluntarily participated in the phase-out of these chemicals because they are damaging to the ozone layer. One category of chemical replacements for CFCs are hydrofluorocarbons. Most are strong greenhouse gases. Would it be fair to require reduction of emissions of this gas before other greenhouse gases have been abated at least somewhat? Similarly, the American economy has become more energy efficient since the oil price shock of 1973. A dollar of GDP in the late 1990s requires roughly only 70 percent as much energy as a dollar of GDP in the early 1970s. During that time period, energy efficiency in the industrial sector increased much more rapidly than in the transportation or commercial or residential sectors (EIA 1997a). On the other hand, if opportunities for further improvements in energy efficiency are still as good in the industrial sector as other sectors, why should one consider granting the industrial sector special status? That is, if a disproportionate burden for future action does not exist, the case for credit for past abatement on fairness grounds seems weak.

Last, the United States has historically provided tax incentives for investment in oil and gas production (for example, depletion allowances). To the extent these incentives have induced behavior that would not have otherwise occurred, changes in the tax code or adoption of policies that penalize this behavior might be deserving of compensation.[26] When a narrowly focused policy has been revoked or superceded by another policy that penalizes behavior that was previously solicited, Congress has on occasion viewed compensation as appropriate (Perlman 1996).

ARE POLICIES THAT DO NOT RAISE REVENUE FAIR?

No, if fairness means taking responsibility for one's actions. Although compensation for every impact of human-induced climate change or policies to control climate change is not justifiable, there are many instances in which compensation will be appropriate. Funding through general taxes fails to hold polluters (both businesses and individuals) responsible for the costs of their actions. Those who damage others by emitting pollutants should pay for clean-up or compensation for those damages. If not, individuals or taxpayers collectively will have to pay for messes created by others.[27]

26. A more specific and worthy example than depletion allowances is the Section 29 tax credit for natural gas from specified unconventional source put in operation prior to 1993. The largest source of production that receives this tax credit (EIA 1999) is coal bed methane, largely from the San Juan Basin in New Mexico but also from Alabama and Wyoming. If coal mining became sufficiently unprofitable due to climate policy, investments made specifically in response to Section 29 might be rendered unprofitable. Since some of these investments capture methane that was previously emitted, these investments have helped to reduce GHG emissions. It seems to us that a good case can be made that investors in them should be compensated for losses, if any, due to climate policy.

27. If each person paid taxes or was damaged in exact proportion to the amount of pollution they emit, including the emissions embodied in the goods and services they purchase, no inequity would exist. But the world we live in does not satisfy either of these theoretical conditions.

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