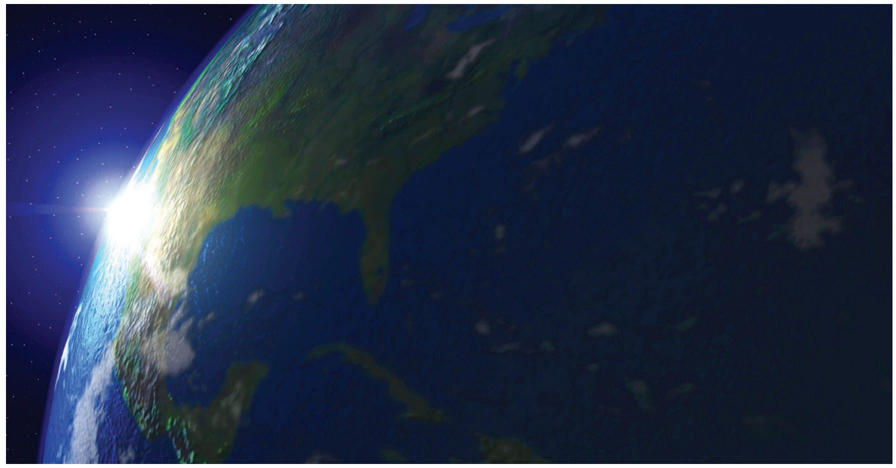
The U.S. Climate Task Force



Addressing Climate Change

Without Impairing the U.S. Economy:

The Economics and Environmental Science of Combining a Carbon-Based Tax and Tax Relief

Robert Shapiro, Nam Pham and Arun Malik

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Addressing Climate Change Without Impairing the U.S. Economy:

The Economics and Environmental Science of Combining a Carbon-Based Tax and Tax Relief[1]

Introduction

Among all of the serious threats and risks to the future health and prosperity of the United States and the world, climate change is one that can be addressed and mitigated with resolve and dispatch. Its gravity is not a matter of scientific doubt. Without serious measures to reduce worldwide emissions of carbon dioxide (CO_2) and other greenhouse gases (GHG), their concentrations in the atmosphere over coming decades will reach levels that scientists now believe will disrupt weather conditions, agriculture and ecosystems around the world, raise sea levels along coasts where many of the world's major cities are located, and may increase the frequency and severity of hurricanes, tornadoes, droughts, floods and monsoons. Scientists also have established that most of these emissions come from burning carbon-based fossil fuels to power the economies of every country in the world. Further, public opinion surveys find that majorities in most countries accept these scientific judgments, from the United States and the nations of Europe to China and Latin America, and support serious action. Yet little has been done to reduce the risks of climate change, because those steps unavoidably will involve major changes in the energy sources and uses that every society depends upon to run its offices and factories, for virtually every form of transportation, and to heat, cool and operate everyone's homes.

This study examines a strategy that promises to reduce those emissions to a path that can sustain the world's climate, at the least cost to the world's economies and with the smallest burdens on their people: Apply a charge or tax to the use of any form of energy based on its carbon content, and recycle the revenues to provide tax relief for the people and businesses using the energy and paying the tax, and for new supports for climate-related research and development, and deployment of climate-friendly fuels and technologies. This tax-shift strategy would apply a new charge on carbon that would start at \$14 per metric ton of CO_2 in 2010 and increase gradually to \$50 per metric ton in 2030, and recycle 90 percent of the revenues in rebates on payroll taxes to employees and employers, or their equivalent in direct payments to households. The remaining 10 percent of the carbon-tax revenues would be used to support energy and climate-related research and development, and new technology deployment.

Our analysis employed the National Energy Modeling Systems (NEMS) model to estimate the environmental results and economic consequences over the next 20 years of applying this strategy, compared to the results expected under "business-as-usual" conditions, currently projected by the Energy Information Agency (EIA) of the U.S. Department of Energy. The NEMS is the computer-based mathematical model of the interactions of U.S. energy markets and the economy developed and maintained by the EIA and used by the agency to conduct periodic short- and long-term forecasts. The NEMS is available for public use, and can simulate the probable environmental and economic results of a range of policy alternatives by altering certain assumptions within the model.[2] This analysis relies on two NEMS simulations and their associated projections for the period 2010 to 2030: (1) a "business-as-usual" scenario using current trends and conditions as projected by the EIA; and (2) a "tax-shift" scenario based on the policies outlined above.[3]

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1 This is the initial study of the U.S. Climate Task Force, a project of Sonecon, LLC. Lessly Goudarzi and Sharon Showalter at OnLocation, Inc., conducted the simulations using the NEMS model and provided extensive technical advice. The analysis and conclusions are solely those of the authors.

2 Office of Integrated Analysis and Forecasting, Energy Demand and Integration Division; Energy Information Administration; http://www.eia.doe.gov/bookshelf/models2002/int.html.

3 OnLocation, Inc., performed the simulations that produced these projections using the NEMS.

The political, social and economic challenges are to reduce CO_2 emissions, and preserve the long-term health of the global climate, with policies that also minimize the current and ongoing costs for economies, and at least most of their people and businesses.

The results of the NEMS simulations of these alternatives are striking and encouraging:

Under current, "business-as-usual" conditions and trends, the EIA projects that over the period of 2004 to 2030:

- Consumption of coal and liquid petroleum, the most highly carbon-intensive forms of energy, will expand by much as 40 percent in the United States and across the world.
- By 2030, CO_2 emissions will increase by nearly 60 percent, including increases of nearly 40 percent in the United States, some 80 percent in Latin America, Africa and the Middle East, and more than 120 percent in the developing areas of Asia.
- Atmospheric concentrations of CO_2, currently estimated at 377 parts per million by volume (ppmv) are projected to rise along a path that would double current concentration levels by the year 2100.

Such increases would present a very grave threat to the world's climate, as a range of scientific studies has concluded that the world's current climatic conditions can be sustained if atmospheric CO_2 concentrations do not exceed a general range of 450 to 550 ppmv over the long term. Stabilizing carbon dioxide concentrations at those levels will require sharp reductions in net global emissions of CO_2 for the next several decades.

A carbon-based tax that would reduce U.S. carbon dioxide emissions consistent with a long-term path to safe levels and with America's role in worldwide emissions would require a charge of about $50 per metric ton of CO_2, or about $180 per metric ton of carbon (in 2005 dollars). Introducing a carbon-based charge that would rise gradually from $14 per metric ton of CO_2 in 2010 to $50 per metric ton in 2030 should steadily move businesses and households to prefer less carbon-intensive fuels, use less energy-intensive technologies and products, and conduct their businesses and lives in other ways that use less energy. We employed the NEMS model to simulate the economic and environmental effects of applying this carbon charge scenario in the United States from 2010 to 2030, while recycling 90 percent of the revenues in payroll tax rebates. Compared to the EIA's "business-as-usual" scenario, this policy shift would have the following effects:

- Total U.S. energy use would increase slowly, and by 2030 Americans would consume 7 percent less energy than they would under current conditions and trends.
- More important for climate change, Americans' use of the least carbon-intensive forms of energy, renewable fuels, would rise sharply (up 220 percent by 2030) while the use of coal, the most carbon-intensive fuel, would fall correspondingly (down 54 percent by 2030). Much of this shift would occur in the fuels used to produce electrical power.
- By 2030, these shifts would drive down U.S. annual CO_2 emissions by about 30 percent, compared to what they would be without a climate change program, or about 6 percent less than current emissions.
- These emission levels would move the United States toward a path that, relative to the U.S. role in global emissions over the next 25 years—and hence assuming comparable participation by the world's other significant GHG producers—would greatly help to stabilize atmospheric CO_2 concentrations at levels of 450-550 ppmv by 2050 and beyond, the levels viewed by most climate scientists as likely to avert the most serious risks of climate change.

The political, social and economic challenge is to reduce CO_2 emissions, and preserve the long-term health of the global climate, with policies that also minimize the current and ongoing costs for economies, and at least most of their people and businesses. Every approach to climate change—carbon-based taxes, cap-and-trade programs or regulation—ultimately involves higher energy prices for households and businesses. By capturing those price increases in a tax, the strategy analyzed here can recycle or rebate most of the revenues through other forms of tax relief, sharply reducing the direct costs for almost everyone. This approach also should minimize most of the indirect costs of the tax as businesses and households adjust to higher energy prices, and retool themselves to head off climate change. The simulations using the NEMS model estimate that from 2010 to 2030:

- A carbon-based tax rising from $14 to $50 per metric ton of CO_2 over the 20 years would generate nearly $4 trillion (all figures are in 2005 dollars unless noted). Compared to current trends, the tax considered alone would cost an average-income household $1,563 per year from 2010 to 2030—including the additional costs to heat, cool and operate a home, drive cars and take trains, airplanes and buses, and produce and distribute all the goods and services an average household consumes. This estimate probably overstates the direct burden on households, as some businesses will be unable to pass along all of their additional energy costs, and the tax could drive energy-related innovations that also will reduce its burden.

- This policy then would return to workers, businesses or households nearly $3.6 trillion of the $4 trillion collected by the tax. These recycled revenues would be sufficient to reduce, on average, the annual payroll tax rate for workers and businesses by two percentage points, or exempt from payroll tax the first $10,066 in a worker's earnings (or exempt the first $5,033 from the payroll taxes paid by both workers and their employers), or provide every working person a rebate payment of $1,080 each.

- These revenues also could be returned as flat payments to every household averaging $1,275 per year, per household, from 2010 to 2030. These payments would more than offset the direct tax-related costs for the majority of American households, since the $1,563 in direct costs applies to the "average-income" household, whose income in 2006 was $66,570 (in 2006 dollars) or nearly 40 percent higher than the "median household income" of $48,201 (in 2006 dollars).

Every serious approach to climate change also involves many indirect costs, as higher energy prices cut into consumption and investment for everything else, and as utilities, businesses and households gradually retool or replace their technologies, equipment, automobiles and appliances to use low-carbon fuels, and achieve greater energy efficiency. Under a carbon-based tax, those indirect costs also should be modest. Our NEMS simulation projects that:

- American GDP would expand 33.4 percent from 2010 to 2020 with a carbon-based tax program, compared to 33.6 percent under business-as-usual, and then expand another 31.0 percent from 2020 to 2030, compared to 31.7 percent without the program. After 20 years, U.S. GDP in 2030 would be $22.3 trillion with a carbon-based tax strategy in place, or about eight-tenths of one percent less than the $22.5 trillion forecast for GDP in 2030 under the business-as-usual scenario (all figures, again, are in 2005 dollars).

- This policy approach also would have only very modest effects on unemployment and inflation. Over the 2010-2030 period, the unemployment rate with the carbon-based tax program in place would be an average of one-tenth of one percent higher than under current trends. Under the program, overall price levels would rise by 51.2 percent from 2010 to 2030, compared to 49.1 percent under current trends, with most of the 2.1 percentage-point difference directly reflecting the impact of the tax on energy prices.

- The indirect economic effects from creating a path to preserve the climate, considered together, would have only a very modest impact on the prosperity of an average-income American household. Households would earn an average of $88,330 per year under the carbon-based tax package, compared to $89,761 under current trends.

This analysis and projections fairly establish that the United States should be able to use this strategy to reduce its emissions to levels consistent with global targets that are broadly considered

necessary to avert serious climate changes, at an average annual cost of 1.6 percent of an average household's annual income.

Moreover, the costs to American households and businesses could be considerably less, because, as noted, the strategy dedicates 10 percent of the carbon-tax revenues to energy and climate change-related R&D and technology deployment. From 2010 to 2030, this would generate almost $400 billion for these purposes, an average of nearly $19 billion per year or almost six times the resources currently invested in energy R&D (in 2005 dollars). No one can know what technological advances will emerge from this expanded support, or when, but there has been a general relationship in the past between R&D levels and the pace of innovation in energy-related areas.

Coupled with the direct incentives from the carbon-based tax itself to develop new and more climate-friendly fuels, technologies, materials and products, this large increase in R&D support could lead to breakthroughs and advances that would reduce emissions even more rapidly and sharply than forecast by the NEMS model, and at even lower costs to the economy, and American businesses and households. The scientific and technological progress supported by this strategy also could change the mix of fuels used to reduce U.S. CO_2 emissions. Progress in nanotechnology, for example, could expand the role of solar power beyond that forecast, and advances in "integrated gasification" and "carbon sequestration" technologies could preserve a major role for coal in a more climate-friendly economy and society.

Climate change policy faces manyfold challenges. Over the last 10 to 15 years, climate scientists have resolved the threshold questions. The Intergovernmental Panel on Climate Change (IPCC), the scientific body established by the United Nations Environment Program and the World Meteorological Organization to evaluate the risks of climate change caused by human activity, has issued comprehensive reports on worldwide climate change research. The IPPC reports are widely considered to be the authoritative statements on the scientific understanding of climate change.[4] The IPCC's Fourth Assessment Report, issued in May 2007, concluded that "[w]arming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." The report cites changes in arctic temperatures as well as widespread shifts in precipitation, ocean salinity, wind patterns and incidences of extreme weather events, including droughts, heat waves and intense tropical cyclones.[5] Further, the IPCC estimates a probability of 90 percent or greater that most of these developments can be traced to increases in GHG and that human activities are a very significant factor. Finally, the IPCC has concluded that current national policies will not stop accelerating increases in atmospheric GHG and that further action is needed to address potentially grave threats to the world's climate.[6]

Many of the world's most-respected scientific organizations endorse these conclusions. Before the 2007 G-8 summit, the national science academies of the G-8 countries (plus academies from five other major nations) issued a public warning, that "[i]t is unequivocal that the climate is changing, and it is very likely that this is predominately caused by the increasing human interference with the atmosphere. These changes will transform the environmental conditions on earth unless countermeasures are taken."[7] Similarly, the Board of Directors of the American Association for the Advancement of Science declared recently that "[t]he scientific evidence is clear: global climate change caused by human activities is occurring now, and it is a growing threat to society." The American Meteorological Society, the American Institute of Physics, the American Astronomical Society, the American Physical Society and the Geological Society of America all have issued similar warnings.

The IPCC's Fourth Assessment Report, issued in May 2007, concluded that "[w]arming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level."

While the expert consensus is solid on the big questions, climate scientists are unable to say precisely how climate changes will affect particular regions and countries, when the climatic processes producing these effects will become irreversible, and when the most serious effects will actually unfold. Public attitudes reflect both the overall scientific consensus and the uncertainties about certain of its features. For a decade or more, people in the United States and other major countries have recognized the problem and supported measures to address it. Surveys in 2005 found 86 percent of Americans supporting "strong steps" to reduce greenhouse gases,[8] a 2007 Gallup study found 60 percent of Americans convinced that global warming has started,[9] and another survey conducted by Yale University, Gallup and the ClearVision Institute

4 IPCC, Mandate and Membership of the IPCC, http://www.ipcc.ch/about/index.htm.
5 IPCC, Fourth Assessment Report, 2007.
6 *Ibid.*
7 Joint Sciences Academies, "Statement on Growth and Responsibility: Sustainability, Energy Efficiency, and Climate Protection," May 2007. http://65.109.167.118/pipa/pdf/jul05/ClimateChange05_Jul05_rpt.pdf.
8 Program on International Policy Attitudes, "Americans on Climate Change: 2005," University of Maryland, http://65.109.167.118/pipa/pdf/jul05/ClimateChange05_Jul05_rpt.pdf.
9 Gallup News Service, "Americans Assess What They Can Do to Reduce Global Warming," Princeton, NJ, April 2007. Another recent survey by Time Magazine, ABC News and Stanford University found that 85 percent of Americans believe that global warming is "probably happening," and 88 percent believe it poses "a threat to future generations." See Langer, Gary, "Poll: Public Concern on Warming Gains Intensity," ABC News, 26 March 2006.

found that 62 percent of Americans believe climate change constitutes an "urgent threat."[10] Similarly, 58 percent of Americans polled by Gallup said that changes to the weather and climate if no action is taken are likely to be "major" or "extreme."[11] A majority of Americans—57 percent—also believe that human activities are the main source of global warming.[12]

People around the world share generally the same views. An analysis of international polling on climate change by the Pew Foundation found that majorities in 37 countries consider global warming a serious threat or problem, and majorities in 25 and pluralities in another six countries rate the threat as "very serious." Similarly, a 2006 survey of 12 major countries by the Chicago Council on Global Affairs and WorldPublicOpinion.org found majorities in all but one nation (India) support action to address the problem; and a 2007 study by the BBC, GlobalScan and PIPA found majorities in 15 of 21 countries favoring prompt and major policy changes. The greatest support for action now was found in Spain (91 percent), Italy (86 percent), and France (85 percent); and as high as 70 percent support was found in China.[13]

While surveys also find that a significant majority of Americans supports certain immediate actions[14]—two-thirds support a 35-mile-per-gallon fuel standard for automobiles, even if it raises car prices by $500, and 64 percent favor stricter energy-efficiency standards for buildings—nearly 50 percent strongly oppose higher electricity or gasoline taxes and another 20 percent to 25 percent are "somewhat opposed."[15] Similarly, while a 2007 review of public opinion in 12 countries found that 85 percent of Americans see climate change as an "important" or "critical" threat, only 43 percent support steps that would involve "significant costs."[16] When people cannot know how much a problem will cost, or when those costs will come due, most are unable or unwilling to say what steps they would take and at what cost to resolve it. From an economist's perspective, people cannot determine how much they would be willing to pay, when they do not know the size or timing of the payoff.

The current conundrum for policymakers is that it is not enough for scientists and public officials to say, even definitively, that unless the world sharply reduces its GHG emissions, their concentrations will produce major changes in the climate with potentially terrible effects. Most people have few if any personal resources to spare, and so they will not accept or support paying significant costs today to head off problems in the future, which no one can describe precisely.

A consensus that dire events will occur in the near future would catalyze serious action; but because GHG remain in the atmosphere for some 100 years, by the time scientists can make such definitive statements, it will be too late to take steps to prevent them.

There are two ways to reconcile science and public attitudes under conditions of great uncertainty: Wait for the science to resolve itself and for public attitudes to shift accordingly; or reduce the costs of responding today to future risks, while their precise dimensions and timing remain unknown. These alternatives can be stated directly. We can wait to take serious steps until scientists can say with confidence

10 Leiserowitz, Anthony, "American Opinions on Global Warming," Yale University/Gallup/ClearVision Institute, Princeton, NJ, July 2007. Similarly, another recent survey by the Chicago Council on Global Affairs reported that 85 percent of Americans see global warming as a possible threat to the United States in the next 10 years, and 46 percent consider it a critical threat. The Chicago Council on Global Affairs, "2006 Chicago Council Public Opinion Survey," July 2006, www.thechicagocouncil.org.

11 Gallup News Service, "Americans Assess What They Can Do to Reduce Global Warming," Princeton, NJ, 2007.

12 Leiserowitz, Anthony, "American Opinions on Global Warming," Yale University/Gallup/ClearVision Institute, Princeton, NJ, July 2007.

13 Kull, Steven, "International Polling on Climate Change," WorldPublicOpinion.org, December 2007; Brewer, Thomas L., "Public Opinion on Climate Change Issues in the G8+5 Countries," March 2007.

14 The Chicago Council on Global Affairs, "2006 Chicago Council Public Opinion Survey," July 2006, www.thechicagocouncil.org/; Gallup News Service, "Americans Assess What They Can Do to Reduce Global Warming," Princeton, NJ, April 2007.

15 Leiserowitz, Anthony, "American Opinions on Global Warming," Yale University/Gallup/ClearVision Institute, Princeton, NJ, July 2007.

16 Chicago Council of Global Affairs and WorldPublicOpinion.org, "Poll Finds Worldwide Agreement that Climate Change Is a Threat, Public Divides Over Whether Costly Steps Are Needed," www.worldpublicopinion.org/pipa/pdf/mar07/CCGA+_ClimateChange_article.pdf.

that soon, for example, the first 10 miles of the East Coast of the United States will be under water and the Southeast will become a savannah. A consensus that dire events will occur in the near future would catalyze serious action; but because GHG remain in the atmosphere for some 100 years, by the time scientists can make such definitive statements, it will be too late to take steps to prevent them.

The alternative approach is to take steps now in ways that can contain the burden on most people and the economy, so the public is willing to support the policy, even with great uncertainty about the long-term consequences and timing of climate changes. Here, too, there are two possible approaches. The first is to take weak actions that most people will accept, even with all the uncertainties. A singular example of that course is the Kyoto Protocol. As many analysts have concluded, the terms of Kyoto effectively exempt from real burdens not only all developing nations (including major CO_2 producers such as China, India and Brazil), and Russia, and the countries that had made up the Soviet Union and its client states in Eastern and Central Europe, but also Germany and Britain.[17] The countries that faced large costs under Kyoto were the United States and Australia, who both withdrew from the agreement, and Japan and Canada, who limited their costs by reinterpreting the terms of the agreement. The downside of Kyoto is that its weak approach will produce little progress on climate change.

The other alternative is to take strong steps now that would address climate change over time, along with additional measures that can offset the cost for individuals in ways that will not reduce the strategy's effectiveness. This study examines one such approach: Apply a tax or charge to fuels based on their carbon content, at the levels required to reduce emissions sufficiently to move to a path that over time would stabilize GHG concentrations in the atmosphere at sustainable levels; and use most of the revenues to reduce other taxes for people and businesses. This strategy would change the relative price of different forms of energy based on their carbon content, so that people and businesses have strong incentives to shift to alternative and less carbon-intensive fuels, and more energy-efficient technologies. The consequent economic burden on individuals and businesses would be largely offset by reductions in payroll taxes or in their effective burden, increasing the public's willingness to accept a carbon-based tax.

Our analysis found that this strategy can reduce GHG emissions in the United States to levels consistent with substantially lowering the risks and threats of climate change, without slowing economic growth or reducing gains in people's incomes to a significant degree, or imposing a regressive burden on low- and moderate-income Americans.

17 Shapiro, Robert J., "Addressing the Risks of Climate Change: The Environmental Effectiveness and Economic Efficiency of Emission Caps and Tradable Permits, Compared to Carbon Taxes," American Consumer Institute, February 2007, http://www.aci-citizenresearch.org/Shapiro.pdf.

To determine the measures that could substantially reduce the risks of climate change, we begin with forecasts of U.S. and global CO_2 emissions if nothing is done, the equivalent of the "business-as-usual" scenario projected by the EIA. We rely throughout this analysis on the National Energy Modeling System (NEMS), the model of energy markets and the economy used by the EIA. This model shows global CO_2 emissions growing by an average of 1.8 percent per year from 2004 to 2030 under current, business-as-usual conditions. If no serious action is taken by the major CO_2-producing nations, global emissions are forecast to rise from 26.9 billion metric tons of CO_2 in 2004 to 33.9 billion metric tons in 2015 and 42.9 billion metric tons in 2030, an increase of nearly 60 percent (Table 1, below). The largest increases in absolute terms will come from North America, because the U.S. economy is so large and energy intensive, and from China, India and other Asian developing nations, because those economies are industrializing very rapidly and becoming much more energy intensive.

The EIA projections also show clearly the rapidly growing responsibility of the large developing and transitional nations for total worldwide greenhouse gas emissions (Table 2, below). In 2004, non-OECD countries (developing economies) and OECD countries (advanced economies) each produced half of the world's CO_2 emissions. By 2030, the advanced world's share of annual worldwide emissions is expected to be down to less than 39 percent, while the share produced by non-OECD nations will reach more than 61 percent. Even so, CO_2 emissions are

Table 1

Business As Usual: World Carbon Dioxide Emissions by Region, 2004-2030
(in millions of metric tons of carbon dioxide equivalent)[18]

Region	2004	2015	2030	Change, 2004-2030
World	**26,922**	**33,889**	**42,880**	**59.3%**
Advanced Nations (OECD)	**13,457**	**14,692**	**16,654**	**23.8%**
North America	6,893	7,780	9,400	39.2%
Europe	4,381	4,558	4,684	6.9%
Asia	2,183	2,353	2,569	17.7%
Developing Nations (Non-OECD)	**13,465**	**19,197**	**26,226**	**94.8%**
Europe & Eurasia	2,819	3,301	3,878	37.6%
Asia	7,411	11,404	16,536	123.1%
Middle East	1,289	1,788	2,306	78.9%
Africa	919	1,291	1,655	80.1%
Central & South America	1,027	1,413	1,851	80.2%

Table 2

Business As Usual: Carbon Dioxide Emissions by Region, As a Share of Global Emissions, 2004-2030[19]

Region	2004	2015	2030	Change, 2004-2030
World	**100.0%**	**100.0%**	**100.0%**	**–**
Advanced Nations (OECD)	**50.0%**	**43.4%**	**38.8%**	**- 22.4%**
North America	25.6%	23.0%	21.9%	- 14.5%
Europe	16.3%	13.5%	10.9%	- 33.1%
Asia	8.1%	6.9%	6.0%	- 25.9%
Developing Nations (Non-OECD)	**50.0%**	**56.6%**	**61.2%**	**+ 22.4%**
Europe & Eurasia	10.5%	9.7%	9.0%	- 14.3%
Asia	27.5%	33.6%	38.6%	+ 40.4%
Middle East	4.8%	5.3%	5.4%	+ 12.5%
Africa	3.4%	3.8%	3.9%	+ 14.7%
Central & South America	3.8%	4.2%	4.3%	+ 13.2%

18 EIA, International Energy Outlook 2007; http://www.eia.doe.gov/oiaf/ieo/ieorefcase.html.
19 *Ibid.*

Table 3

Business As Usual: Projected Increase in Energy Use by Region and Fuel, 2004-2030[20]

	World	OECD	U.S.	Non-OECD
Increase in Energy (Quadrillion BTUs)	**254.8**	**58.3**	**24.3**	**196.4**
Liquids (%)	42.0%	15.7%	24.5%	79.5%
Coal (%)	73.9%	27.3%	40.0%	105.9%
Natural Gas (%)	64.8%	36.2%	9.0%	95.0%
Nuclear (%)	44.4%	7.0%	8.7%	188.4%
Hydropower/Renewables (%)	61.1%	38.0%	24.5%	18.2%

Table 4

Business As Usual: World Carbon Dioxide Emissions by Region and Fuel Source, 2004-2030 (in millions of metric tons of carbon dioxide equivalent)[21]

	2004	2015	2030	Change, 2004-2030
Liquids				
World	10,852	12,735	15,411	42.0%
OECD	6,314	6,538	7,293	15.5%
U.S.	2,598	2,799	3,318	27.7%
Non-OECD	4,538	6,153	8,118	78.9%
Coal				
World	10,617	14,057	18,466	73.9%
OECD	4,345	4,727	5,536	27.4%
U.S.	2,115	2,407	3,206	51.6%
Non-OECD	6,272	9,330	12,930	106.2%
Natural Gas				
World	5,441	7,083	8,988	65.2%
OECD	2,786	3,369	3,810	36.8%
U.S.	1,198	1,369	1,412	17.9%
Non-OECD	2,655	3,714	5,178	95.0%

growing globally: Carbon dioxide emissions by OECD countries are expected to increase from roughly 13.5 million metric tons in 2004 to 16.7 million metric tons in 2030, or about 24 percent; while the emissions of non-OECD countries are forecast to jump nearly 95 percent, from about 13.5 million metric tons in 2004 to 26.2 million metric tons in 2030. (See Table A.24, Appendix, for projected growth rates in CO_2 emissions by major countries.)

Under current conditions with no policy changes–business as usual—global coal consumption is forecast to rise 74 percent from 2004 to 2030, natural gas consumption will increase 65 percent, and hydropower and other renewables will expand 61 percent. In absolute terms, the greatest increases will come from coal (up 84.6 quadrillion BTUs), natural gas (up 67 quadrillion BTUs) and petroleum products (up 70.7 quadrillions BTUs). A closer analysis shows that 77 percent of the increases in worldwide energy use will come from non-OECD countries; and of the remaining 23 percent, the United States will account for nearly seven-tenths of that (Table 3, above and Table A.25, Appendix). However, worldwide and across the non-OECD countries, the fuel accounting for the largest share of these increases is the most carbon-intensive energy source—coal; across advanced countries, natural gas accounts for the largest share of their increases in energy use, and in the United States, those increases are concentrated in petroleum products and coal.

The data and projections show that a serious climate change program will have to include both the United States and the large developing nations, and directly or indirectly, must reduce coal use. From 2004 to 2030, CO_2 emissions from coal will grow faster and exceed those from petroleum products or natural

20 EIA, International Energy Outlook 2007; http://www.eia.doe.gov/oiaf/ieo/ieorefcase.html.
21 *Ibid.*

gas; and by 2030, developing nations will account for 50 percent more emissions than OECD countries and for two-thirds of coal-related emissions. Throughout this period, the United States will remain the largest producer of petroleum-related emissions. (Table 4, previous page).

Atmospheric Carbon Dioxide Concentrations

Climate scientists cannot say precisely how rapidly atmospheric concentrations of CO_2 and other greenhouse gases will rise—the point at which serious climate changes will become irreversible—and consequently how quickly and by how much emissions must be reduced. However, they can and do say that in order to stabilize these concentrations at levels believed to be safe for the global climate, global, annual net CO_2 emissions eventually will have to be reduced to a small fraction of their current levels. The lower the concentration levels deemed necessary for the global climate, the sooner the reductions in net annual emissions will have to begin and the greater those reductions will have to be. Those concentrations are currently about 377 parts per million by volume (ppmv), compared to 280 ppmv in preindustrial times and 354 ppmv in 1990. The U.N. Intergovernmental Panel on Climate Change (IPCC) has issued six emissions scenarios, based on the pace of economic development and whether serious action on climate change occurs, projecting atmospheric CO_2 concentrations in the year 2100 ranging from 540 to 970 ppmv (with -10 percent to +30 percent variation).[22] The U.S. Environmental Protection Agency's (EPA) base case scenario, assuming no U.S. or international action on climate change, estimates global CO_2 concentrations in 2095 of some 718 ppmv.[23]

Scientific views of the levels of CO_2 and other GHG concentrations that would be environmentally tolerable range from 400 ppmv to 550 ppmv. Two prominent researchers from Princeton University, Stephen Pacala and Robert Socolow, for example, adopt a goal of 500 ppmv and estimate that stabilizing CO_2 concentrations at that level would require an annual cap on worldwide CO_2 emissions for the next 50 years of roughly 27 billion metric tons, the global emissions level in 2004.[24] Another expert, Niklas Hohne, a German physicist and officer of the United Nations Framework Convention on Climate Change, has concluded that the safe level of concentrations is closer to 400 ppmv, which would require 3 percent annual reductions in global emissions starting immediately and continuing for decades.[25] A comprehensive review of climate change research conducted for the British government by the Stern Commission concluded that the appropriate goal should be atmospheric CO_2 concentrations of 440 to 500 ppmv. The Stern Commission estimated that those levels could be achieved by 2050 by reductions in emissions of 1 percent to 3 percent per year.[26] Under this path, annual emissions in 2050 would be 25 percent lower than today in a global economy four times as large as today. The IPCC has adopted the goal of stabilizing CO_2 concentrations at 550 ppmv and projects that establishing a path to this goal will require limiting global emissions to no more than 6 billion metric tons of carbon dioxide per year by 2010, the level of CO_2 emissions in 1990, and declining over a very long term to less than 2 billion metric tons per year.[27]

We adopt as our target emissions levels one that will, consistent with the U.S. role in global emissions, produce a path of future emissions that should stabilize CO_2 atmospheric concentrations at 450 to 550 parts per million by volume through the 21st century and beyond. This analysis assumes, as do all other serious proposals and scenarios for addressing climate change, that GHG-producing nations all take steps consistent with their roles in rising atmospheric concentrations of CO_2 and other GHG, including major developing nations.

22 "Climate Change 2001: Synthesis Report – Summary for Policymakers," IPCC Third Assessment Report, IPCC, 2001; http://www.ipcc.ch/pdf/climate-changes-2001/synthesis-spm/synthesis-spm-en.pdf.
23 "EPA Analysis of the Climate Stewardship and Innovation Act of 2007," S.280 in 110th Congress, EPA, 2007.
24 Pacala, Stephen and Socolow, Robert, "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies," *Science*, Vol. 305, August 13, 2004, pp. 968-971, http://carbonsequestration.us/Papers-presentations/htm/Pacala-Socolow-ScienceMag-Aug2004.pdf.
25 Hohne, Niklas, "Impact of the Kyoto Protocol on Stabilization of Carbon Dioxide Concentration," ECOFYS Energy & Environment, 2005; http://www.stabilisation2005.com/posters/Hohne_Niklas.pdf
26 Stern, Nicholas, "The Economics of Climate Change: the Stern Review," Cabinet Office, HM Treasury; http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm.
27 "EPA Analysis of the Climate Stewardship and Innovation Act of 2007," S.280 in 110th Congress, EPA, 2007.

There are three broad policy approaches to contain climate change. One strategy would use command-and-control regulations to cap CO_2 and other GHG emissions by industry or producers. Most experts, especially most economists, agree that such command-and-control regulation of energy use would entail high and largely unnecessary economic costs. Such regulation is highly inefficient, since it would impose the same caps on energy use or emissions on producers who could meet them at relatively little cost as it would on others who would face much higher costs. Such regulation also is likely to produce bottlenecks and fast-rising prices when demand for products collides with the producers' caps. A second approach would cap emissions, while permitting producers to sell and purchase permits to produce emissions up to their caps. This "cap-and-trade" strategy is more efficient than simple regulation, because those who could cut their emissions inexpensively will do so and sell their excess permits to those whose cost of cutting emissions would be greater than the price of the permits.[28] While a cap-and-trade approach is less costly to an economy than command-and-control regulation, many economists have concluded that it could be a source of significant new volatility in national energy prices, expensive to administer, prone to manipulation, and very difficult to monitor and enforce.[29]

The third major alternative is to directly tax carbon or CO_2 emissions. Many economists support this approach to climate change, because it would directly and predictably raise the relative price of goods and services based on their carbon intensity, and so directly encourage consumers to prefer less carbon-intensive fuels, and products and businesses to adopt or develop less carbon or energy-intensive materials, technologies, production processes and fuels. Economists and governance experts also note that a carbon tax would not create the new price volatilities, administrative burdens, and large opportunities for evasion and fraud that could characterize a cap-and-trade program. By setting a predictable price for carbon emissions, it also creates clear and known incentives to develop and deploy more climate-friendly technologies and fuels. However, a carbon-based tax approach also has shortcomings. Most important, it cannot guarantee the specified reductions in annual CO_2 emissions promised by command-and-control or cap-and-trade approaches. To overcome this deficiency, a carbon-tax program could include automatic adjustments in its rate to offset shortfalls in forecast CO_2 reductions.

Other objections to a carbon-based tax program are both economic and political. Critics argue that it would raise costs and prices, and would dampen economic growth. They further note that no one favors higher taxes or the economic distortions they can cause, and consequently voters will resist paying a substantial new tax simply to avert unknown, adverse effects decades from now. We propose to address these shortcomings by returning the revenues from a carbon-based tax to households and businesses through other forms of tax relief, so that economic growth and the incomes of most households would be much less affected.

We propose to address these shortcomings by returning the revenues from a carbon-based tax to households and businesses through other forms of tax relief, so that economic growth and the incomes of most households would be much less affected.

This carbon-based tax policy design should be preferable economically and politically to top-down regulation or cap-and-trade programs. To begin, traditional regulation and cap-and-trade programs treat a plant or industry's initial carbon emissions as effectively "free," up to the point of the regulatory ceiling

28 In principal, this strategy would encourage energy and other industrial companies to reduce their emissions so they could sell excess permits, while their costs to reduce emissions or purchase permits would be passed on to consumers and other businesses, encouraging them in turn to favor less carbon-intensive products.

29 To limit the price volatility, a cap-and-trade program could incorporate a "safety valve," in which additional permits would be auctioned or distributed when energy demand increased unexpectedly, straining the cap. See Congressional Budget Office, "Limiting Carbon Dioxide Emissions: Prices versus Caps," CBO Paper, March 15, 2005. The U.S. acid rain program has a safety-valve provision for the trading of SO_2 permits, but its price volatility has continued. Shapiro, Robert J., "Addressing the Risks of Climate Change," op. cit. http://www.aci-citizenresearch.org/Shapiro.pdf.

or cap, while a carbon-based tax extracts a cost for emissions from the first part per million. In addition to the economic costs of introducing new volatility in energy prices, cap-and-trade programs and regulatory caps would impose other administrative and monitoring costs on consumers and businesses that would be generally comparable to a carbon-based tax, only in less obvious ways and in many cases with no additional revenues that could be rebated to offset their effects. Inevitably, a company or industry's expenditures to comply with the regulations or an emissions cap will be passed along in higher prices, just as would a carbon-based tax. While certain variations on cap and trade are designed to duplicate some of the advantages of a carbon-based tax—for example, by limiting how high permit prices can go, and by auctioning permits to generate revenues—consumers and businesses also will end up paying the billions of additional dollars required to administer, monitor and enforce a cap and trade or regulatory system. Regulation also would involve billions of dollars in additional costs to the economy by imposing the same requirements on every plant and industry, regardless of which could help meet the goal most efficiently. Moreover, much as voters would likely oppose significant new, climate-related taxes without offsetting tax relief, they will likely resist climate change regulation or a cap-and-trade program when they recognize the actual costs.[30]

This study analyzes the environmental and economic consequences of adopting a politically acceptable form of a carbon-based tax, in which most of its revenues are used to reduce other taxes on the people and businesses bearing much of the burden. Using the NEMS modeling system, we test the proposition that applying a new tax package on energy sources based on their carbon content, and using 90 percent of the revenues to reduce payroll taxes or their equivalent, could bring down projected CO_2 emissions to a path that should stabilize their atmospheric concentrations at levels safe for the global climate, and without materially affecting most people's incomes or the economy's capacity to grow and create jobs.

30 These expected reactions help explain why the Kyoto Protocol and the current European Trading Scheme, which combines a cap-and-trade program and Kyoto's short-term goals, effectively excuse most countries from the strict requirements that would impose real costs of households and businesses. For an extended discussion of these issues, see Shapiro, *Ibid*.

In one way or another, every strategy to reduce CO_2 emissions depends on using the additional costs of complying with the regulations, caps or taxes to encourage businesses and people to develop new fuels, technologies and products that are less carbon-intensive, and then to deploy them. It is apparent that current market conditions and public support are insufficient to develop and deploy the mix of fuels, technologies and products that could alter the path of climate change. In fact, despite concerns about both global warming and energy security, energy-related R&D has been declining for more than two decades.

Following the 1970s oil shocks, worldwide energy-related R&D almost doubled, from $10.2 billion in 1974 to $18.4 billion in 1980 (in 2005 dollars). U.S. energy R&D rose more than threefold in just five years, from $2.7 billion in 1974 to $8.5 billion in 1979. The steep decline in energy prices starting in the mid-1980s and continuing through the 1990s reversed this trend. Global energy-related government R&D in 2006 was $10.6 billion, approximately half its 1980 levels and, adjusted for inflation, roughly the levels of 1974. Worldwide private-sector R&D in energy also declined. Energy-related R&D also fell sharply in the United States, declining from $8.2 billion in 1979 to $3.1 billion in 2006.[31] The largest decline occurred in private sector R&D, which accounted for 24 percent of all U.S. energy-related R&D in 2005, compared to 50 percent in the 1980s and 1990s.[32]

The policies examined here seek to accelerate the development and deployment of new fuels, technologies and products by channeling 10 percent of carbon-tax revenues to new support for climate change-related R&D and technology deployment. The need for additional measures to the development and large-scale deployment of low-carbon and more energy-efficient technologies has been addressed in detail by Britain's Stern Commission Review.[33] The Stern Review recommends worldwide additional commitments of $76 billion per year for R&D and technology deployment, including doubling public funding for energy-related R&D to some $20 billion per year and increasing incentives for the deployment of more climate-friendly technologies by at least twice their current worldwide levels of $33 billion per year.[34] These supports could be particularly important and effective in fast-growing, modernizing and developing nations such as China. In recent years, China and India have actively encouraged the spread of new technologies to produce and use renewable fuels, and the two countries now have, respectively, the world's single-largest and fifth-largest renewable energy capacities.[35]

This prospect suggests that if the United States were to adopt the policies examined here, scientific and technological advances promoted by those incentives and additional resources could reduce CO_2 emissions even more rapidly and sharply than forecast by the current NEMS model, and perhaps at even lower costs to the economy and American households.

From 2010 to 2030, this program analyzed here would generate $395.7 billion for energy-related R&D and technology deployment (in 2005 dollars), or an average of $18.8 billion per year, compared to recent U.S. public and private investments in energy R&D averaging just $3.1 billion per year. (In current dollars, the program would dedicate $553.4 billion to these purposes over 2010-2030, or an average of $26.4 billion per year). These additional commitments to R&D and technology employment would be

31 OECD/EIA R&D Database; IEA Global includes 26 countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, U.K. and U.S.

32 Nemet, Gregory and Kammen, Daniel, "U.S. Energy Research and Development: Declining Investment, Increasing Need, and the Feasibility of the Expansion," Energy Policy, 2007.

33 Stern, Nicholas, "The Economics of Climate Change: the Stern Review," Cabinet Office, Her Majesty's Treasury, www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm.

34 *Ibid*.

35 *Ibid.*

equivalent to about one-third of the additional global investments envisioned by the Stern Commission Review, which also would correspond generally to America's role in global CO_2 emissions, which has averaged about 30 percent since 2004.[36]

While particular technological advances are unpredictable, economic researchers have found a general relationship between R&D levels and the pace of innovation, including in energy-related areas.[37] Moreover, an enhanced commitment to R&D could strongly reinforce the incentive to develop less carbon-intensive fuels, technologies, materials and products, which a carbon tax already provides by raising the price for energy based on its carbon content. This prospect suggests that if the United States were to adopt the policies examined here, scientific and technological advances promoted by those incentives and additional resources could reduce CO_2 emissions even more rapidly and sharply than forecast by the current NEMS model, and perhaps at even lower costs to the economy and American households.

Intensifying the incentives and resources to develop and deploy more climate-friendly fuels and technologies also could change the mix of fuels used to reduce America's CO_2 emissions. Without significant technological progress, the tax would sharply reduce America's use of coal for energy and sharply increase its use of renewable fuels. The U.S. government already supports initiatives to develop clean-coal technologies, including current research efforts to develop "integrated gasification" technologies that can pressurize coal into a vapor form, filter and capture the CO_2 and other pollutants from the coal gas before burning it, and then "sequester" or store the CO_2 underground or in the oceans. These and other R&D program fuels could succeed with greater resources—or not—and if they do, they will change the way a carbon-based tax program would enable the United States to create a more environmentally sustainable economy and way of life.

36 The base for this calculation includes all major CO_2 producers, including the OECD countries plus China, India and Russia.

37 For example, studies have shown that energy-related patents have generally been positively correlated with R&D spending. U.S. investments in energy-related R&D rose from $7.6 billion in 1976 to $11.9 billion in 1979 and then dropped to $4.3 billion in 1996 (in 1996 dollars). Over the same period, the number of new, energy-related patents rose from 102 in 1976 to 228 in 1981 and then declined to 54 in 1994. See Margolis, Robert and Kammen, Daniel, "Underinvestment: The Energy Technology and R&D Policy Challenge," Energy Viewpoint, 1999.

The goal of an optimally designed carbon-based tax can be stated simply: Reduce carbon emissions at the rate and levels required to move to a path that will stabilize future atmospheric concentrations of CO_2, so they do not produce destructive climatic changes, and in ways that impose the least marginal social and economic costs.

Because climate science is still developing, scientists cannot say with certainty what the marginal cost of CO_2 emissions is today, and consequently at what precise point a carbon-based tax—or the cap in a cap-and-trade program—would achieve this goal. One of the most comprehensive surveys of these issues, conducted by a leading European expert, Dr. Richard S.J. Tol, assessed 103 published estimates of the marginal costs of CO_2, including 43 studies published in peer-reviewed journals.[38] Among these more rigorous analyses, the average or mean value of this measure was $50 per metric ton of carbon or $13.64 per metric ton of CO_2.

This analysis adopts those mean or average values as its starting point: We introduce the tax in 2010 set at $14.05 per metric ton of CO_2 or about $50 per metric ton of carbon (in 2005 dollars).[39] We use the NEMS model to determine the level of tax in 2030 that, applied globally, could reduce annual CO_2 emissions to a path that would stabilize atmospheric concentrations at safe levels of 450-550 parts per million through the end of the 21st century and thereafter. Based on the work of the IPCC and other peer-reviewed research, a stabilization path of atmospheric CO_2 concentrations would require that annual global emissions fall to less than current levels by 2050, even as global economic activity and energy use expand manyfold. The NEMS model estimates that a tax that would rise gradually from $14.05 per metric ton of CO_2 in 2010 to $50.58 per metric ton of CO_2 in 2030 would reduce annual U.S. CO_2 emissions in 2030 to less than their current level. Since atmospheric CO_2 concentrations are a global phenomenon, this analysis must assume that other major CO_2 producers and emitters also would do their share, consistent with their role in emissions. These levels for a carbon-based tax are also consistent with a broad survey of the economics literature conducted by the IPCC in its Fourth Assessment Report of April 2007.[40] The Panel reported that peer-reviewed estimates of the social cost of carbon in 2005 had an average value of $12 per metric ton of CO_2 (about $43 per metric ton of carbon) and ranged as high as $95 per metric ton of CO_2 (about $350 per metric ton of carbon).

We employ the NEMS model to estimate how much and in what ways this path for a carbon tax would change the levels and forms of energy used, by sectors and regions, the economic effects of those changes and the revenues generated by the combination of these effects. The NEMS model produces 25-year annual projections of energy production, consumption and prices, subject to alternative macroeconomic policies and resource availability.[41] The EIA uses the NEMS model to produce its long-term U.S. and global energy forecasts, and recently used it to analyze the impact of two prominent cap-and-trade proposals, the Lieberman-McCain bill (the Climate Stewardship and Innovation Act of 2007, S. 280) and the Bingaman-Specter bill (the Low Carbon Economy Act of 2007, S. 1766).[42] As in these EIA analyses, we analyze the effects for the United States of applying the proposed carbon-based tax, assuming that the United States and other countries will contribute to the global goal of moving atmos-

38 Tol, Richard S.J., "The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," Energy Policy, 2005.

39 To convert $ per metric ton of carbon (mtC) to $ per metric ton of carbon dioxide ($mtCO_2$), multiply the former by 12 and divide by 44. To convert a metric ton of carbon emission to a metric ton of carbon dioxide emissions, multiply the former by 44 and divide by 12.

40 Intergovernmental Panel on Climate Change, "Climate Change 2007: Impacts, Adaptation and Vulnerability," Working Group II Contribution to the IPCC Fourth Assessment Report, April 2007; www.ipcc.ch.

41 National Energy Model System. Energy Information Agency, Department of Energy, www.eia.doe.gov/oiaf/aeo/overview/.

42 Lieberman-McCain's S.280; www.eia.doe.gov/oiaf/servicerpt/csia/pdf/sroiaf(2007)04.pdf; Bingaman-Specter's S.1766; www.eia.doe.gov/oiaf/servicerpt/lcea/pdf/sroiaf(2007)06.pdf.

pheric concentrations of CO_2 toward stabilized levels of 450-550 ppmv, consistent with their share of global emissions. As noted earlier, this stabilization path will require that annual global carbon dioxide emissions fall to less than their current levels by 2030 and thereafter.

In simulating the environmental and economic effects of the carbon-based tax package, including recycling its revenues to other forms of tax relief, and expanded support for climate-related R&D and technology deployment,[43] we modified the NEMS model in one important respect. The model assumes that the capacity of the nuclear power sector, like natural gas and renewable energy sources, can expand to meet rising demand for less carbon-intensive forms of energy without any constraints other than the relative prices of the different fuels. The model's assumption about nuclear power in the United States is unrealistic on any practical basis. The nuclear power industry currently generates about 20 percent of U.S. electricity from 103 licensed reactors at 65 plant sites in 31 states. However, no new nuclear plants have been ordered since 1978, none are currently under construction and orders for more than 100 new reactors have been canceled.[44] Consequently, we adjusted the model to limit the growth in U.S. nuclear power production to 20 percent from 2010 to 2030, equal to its growth rate from 1996 to 2006 and roughly twice the EIA's current baseline projection for nuclear energy from 2010 to 2030. Without this constraint, the NEMS model would project unrealistically that the carbon-based tax would produce a near tripling of U.S. nuclear power generation and use, from 8.2 quadrillion Btu in 2006 to 23.2 quadrillion Btu in 2030.

43 The technology deployment aspect was modeled in the following way: 5 percent of the total allocation for R&D and technology deployment was assumed to benefit energy consumers, and therefore was modeled as a decrease in personal income tax, and 45 percent of the total allocation was assumed to benefit businesses, and therefore was treated by the NEMS model as if it were never collected from businesses. This approach is similar to the treatment in the EIA's analysis of the Lieberman-McCain proposal, S.280.

44 The Nuclear Regulatory Commission has granted 16 commercial reactors 20-year extensions of their licenses, giving them up to 60 years of operation each, and is reviewing license extension applications for 14 more reactors. Parker, Larry and Holt, Mark, "Nuclear Power: Outlook for New U.S. Reactors," CRS Report for Congress, March 2007; www.fas.org/sgp/crs/misc/RL33442.pdf.

The Environmental Impact of the Carbon-Based Tax Package: Changes in the Energy that Americans Would Use and the Consequent Emissions

The NEMS model shows first how a carbon-based tax package, with the revenues recycled through payroll tax relief and increased R&D spending, would affect the forms of energy that American households and businesses would use, if the carbon content were taxed to head off climate change. The overall result is that by 2030, the total energy used by American households, commercial establishments, industries and for transportation would each be about 10 percent less than under the EIA "reference" or business-as-usual case, in which no climate change actions are taken. Much of these energy savings would come from millions of decisions to purchase and use less energy-intensive technologies and products, and people finding countless ways to use less energy as they conduct their businesses and lives. These decisions are evident in the changes in the kinds of fuels American would use. As expected, the use of gasoline and other petroleum products for transportation is lower than if no policy change takes place—but only modestly so, because with or without a carbon tax, the shift to hybrids and other alternative-fuel engines is expected to continue and consequently is built into the reference case. The largest changes involve coal and renewable sources of energy, respectively, the most carbon-intensive and the least carbon-intensive fuels available. Using our assumptions, the NEMS model projects that by 2030, the United States, with the carbon-based tax program, would consume 56 percent less coal and 145 percent more renewables than under current, business-as-usual conditions and trends. These shares would change much less with breakthroughs in clean-coal technologies and scientific efforts to gasify coal, capture the CO_2 from the coal gas and sequester it underground or in the oceans. But, otherwise, coal's share of U.S. energy consumption in 2030 would be less than 12 percent, instead of its projected share of 26 percent in that year, while renewables would account for approximately 15 percent of all energy consumed, instead of their currently projected 6 percent in 2030. (See Tables A.8-A.10, Appendix)

The critical issue for climate change is the effect of these changes on emissions. Petroleum and coal currently account for 43.5 percent and 36.3 percent, respectively, of U.S. CO_2 emissions; and under current conditions and trends, CO_2 emissions from coal will grow nearly 50 percent between 2005 and 2030,

Table 5 **CO_2 Emissions by Fuel: Business As Usual Versus a Carbon-Based Tax Package** (in millions of metric tons of carbon dioxide equivalent)

	2005-2007	2010-2019		2020-2030	
		Business As Usual	Carbon-Based Tax	Business As Usual	Carbon-Based Tax
Annual CO_2 Emissions (mmt)	5,958.9	6,529.4	5,988.8	7,408.2	5,772.2
Petroleum	2,591.8	2,783.4	2,691.3	3,123.6	2,936.8
Natural Gas	1,190.9	1,351.8	1,336.9	1,408.6	1,366.8
Coal	2,164.3	2,381.2	1,944.8	2,862.3	1,451.1
Renewables and Others	11.8	12.9	15.7	13.8	17.6

Table 6 **Share of CO_2 Emissions by Fuel: Business As Usual Versus a Carbon-Based Tax Package**

	2005-2007	2010-2019		2020-2030	
		Business As Usual	Carbon-Based Tax	Business As Usual	Carbon-Based Tax
Annual CO_2 Emissions	100.0%	100.0%	100.0%	100.0%	100.0%
Petroleum	43.5%	42.6%	44.9%	42.2%	50.9%
Natural Gas	20.0%	20.7%	22.3%	19.0%	23.7%
Coal	36.3%	36.5%	32.5%	38.6%	25.1%
Renewables and Others	0.2%	0.2%	0.3%	0.2%	0.3%

Table 7 **CO_2 Emissions in Electric Power Generation by Fuel: Business As Usual Versus the Carbon-Based Tax Package** (in millions of metric tons of CO_2 equivalent)

	2005-2007	2010-2019		2020-2030	
		Business As Usual	Carbon-Based Tax	Business As Usual	Carbon-Based Tax
Annual CO_2 Emissions (mmt)	2,371.8	2,640.7	2,175.9	3,060.9	1,640.5
Petroleum	74.9	73.8	28.4	77.4	23.4
Natural Gas	319.1	372.6	367.0	352.2	319.4
Coal	1,966.0	2,181.3	1,764.8	2,617.6	1,280.1
Renewables and Others	11.8	12.9	15.7	13.8	17.6

and emissions from petroleum will increase by a little more than 26 percent. The application of the carbon-based tax would lead to significant reductions in the use of coal and the associated CO_2 emissions: Over the period 2020 to 2030, annual coal-related CO_2 emissions under the tax package would be half as great as the business as usual and one-third lower than current levels (Table 5, previous page). Moreover, coal's share of all annual emissions over 2020-2030 would fall from nearly 39 percent to just over 25 percent (Table 6, previous page). The reductions in the annual emissions from less carbon-intensive forms of energy, especially petroleum products and natural gas, would be much less; and with the decline in the use of coal and its emissions, their share of total annual emissions would actually rise.

Much of this shift would occur in the fuels used to produce electrical power. Total electrical power use would be 10.6 percent less in 2030 with the carbon-based tax package, including the tax relief, than under business as usual, and the NEMS model projects modest shifts in the use of natural gas and fuel oils, and a slightly larger shift toward nuclear power. Those changes are minor compared to what would likely happen to coal and renewables in electricity generation. From 2005 to 2007, the electric power sector produced an average of 2.4 billion metric tons of CO_2 per year, and coal accounted for 83 percent of those emissions. Moreover, under current trends and conditions, the role of coal in electric power generation is expected to increase. Without action on climate change, 59 percent of all electric power will come from coal by 2030, while renewables will account for just over 10 percent of that generation. A carbon-based tax program will reduce coal use in this sector and its CO_2 emissions substantially: Those emissions would drop from current levels of 2.4 billion metric tons per year to an annual average of 1.6 billion metric tons from 2020 to 2030. Introduce the carbon-based tax program, and by 2030 the share of U.S. electricity generated by coal should fall nearly two-fifths to 36 percent, while the share generated by renewables should rise more than threefold to a comparable 36 percent level. The carbon-based tax would reduce total emissions by the electric sector in 2020-2030 by 30.8 percent and its coal emissions by 34.9 percent, compared to today (Table 7, above). Compared to business as usual, the carbon-based tax would cut electric sector emissions in 2020-2030 by 46.4 percent and its coal emissions by 51.1 percent.

The major impact of a carbon-based tax, therefore, is not on total energy consumption, especially if the revenues are returned through tax relief and public investments, but on the mix of fuels that businesses and households consume. In 2020, total energy use under the carbon-based tax program is estimated by the NEMS model at 113.2 quadrillion BTUs, approximately 4 percent less than the 117.6 quadrillion BTUs projected under business-as-usual conditions (Table 8, next page). By 2030, the difference in total energy use is 7 percent: 121.4 quadrillion BTUs under the carbon-based tax, compared to 130.6 quadrillion BTUs if no action is taken on climate change. Over the 20-year period, U.S. energy consumption would be 4.2 percent less under a carbon-based tax program, compared to the current trends. The impact of the tax strategy comes mainly from the shift from widespread use of very carbon-intensive forms of energy to greater use of more climate-friendly forms of energy, with a major impact on projected CO_2 emissions and climate change. In 2020, those shifts reduce expected emissions from 6,920 million metric tons of CO_2 to 5,977 million metric tons, a difference of 13.3 percent. By 2030, even as total energy consumption continues to expand—though a little more

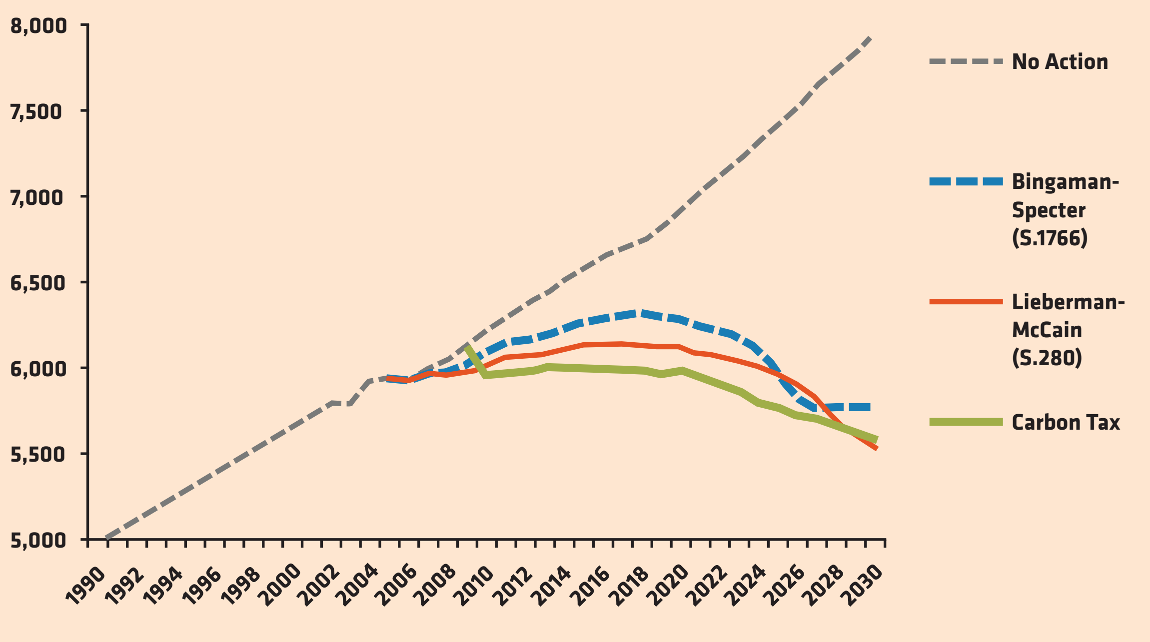
Table 8 **Impact of the Carbon-Based Tax Package on U.S. Energy Consumption and Carbon Dioxide Emissions, 2010-2030**

	2010	2020	2030	Change, 2004-2030
Energy Use (quadrillion BTUs)				
No Action	106.17	117.64	130.55	+ 23.0%
Carbon Tax	104.59	113.18	121.41	+ 16.1%
CO_2 Emissions (million metric tons)				
No Action	6213.6	6920.3	7919.2	+ 27.5%
Carbon Tax	5962.0	5977.3	5572.5	- 6.5%
Impact of Carbon Tax				
Energy Use	- 1.5%	-3.8%	-7.0%	-7.0%
CO_2 Emissions	- 4.1%	- 13.6%	- 29.3%	-29.6%

slowly than without the program—the economic pressures from the tax package continue to drive down CO_2 emissions. The NEMS model finds that in 2030, U.S. CO_2 emissions under the carbon-based tax strategy would be an estimated 5,572 million metric tons, or roughly 30 percent less than the 7,919 million metric tons projected by the EIA in its business-as-usual scenario. In 2030, U.S. emissions under the tax program would be nearly 7 percent less than they were in 2007, while over the same period the U.S. GDP, after inflation adjusted, is projected to grow by more than 90 percent.

The EIA used its NEMS model to estimate the path of CO_2 emissions under two prominent cap-and-trade proposals in the U.S. Senate, the Lieberman-McCain bill (S.280) and the Bingaman-Specter proposal (S.1766). The results are shown in Figure 1, (below), along with our projections using the NEMS model to estimate the impact of the carbon-based tax package: U.S. households and businesses respond more quickly to the carbon-based tax, with lower emissions than either cap-and-trade proposal for the first 10 to 15 years. By 2030, carbon-based tax emissions continue to be lower than emissions

Figure 1 **NEMS Estimates of CO_2 Emissions under the Carbon-Based Tax Program and Two Cap-and-Trade Proposals, 1990-2030**



under the Bingaman-Specter version of cap-and-trade proposal and roughly equivalent to those under the Lieberman-McCain approach.

All of these paths are consistent with a goal to stabilize atmospheric carbon dioxide concentrations at safe levels for the global climate over the long term.

These results are also significant in another respect, because they suggest that the economic incentives and pressures created by the carbon-based tax package should reduce CO_2 emissions as substantially and reliably as the strict caps under two leading cap-and-trade proposals.

A carbon-based tax that can reduce CO_2 emissions sufficiently to substantially mitigate the risks of climate changes will involve large revenues: The NEMS model estimates that the carbon-based tax program analyzed here would generate $3.96 trillion over 2010-2030, or an average of $188.4 billion per year (in 2005 dollars). (In current dollars, it would generate $5.53 trillion over 2010-2030 or an average of $263.5 billion per year.) Those revenues would be returned mainly as tax relief to offset the impact of the new tax on many businesses and most families' finances, with 90 percent of the revenues dedicated to reducing the burden of old age, survivors, and disability insurance (OASDI) payroll taxes and the remaining 10 percent designated for climate change-related R&D and technology deployment. (Table 9, below and Appendix for year-by-year estimates)

If the government recycles the revenues as payroll tax reductions for both employers and employees, the program would reduce the burden of payroll taxes by about $3.6 trillion over 2010-2030, or by an average of about $170 billion per year (in 2005 dollars). This average level is equivalent to 20.8 percent of the payroll taxes collected each year in 2005 and 2006.[45] Allocating the remaining 10 percent of the new revenues to climate change-related R&D and technology deployment would shift about $396 billion to these purposes over 2010-2030, or an average of nearly $19 billion per year. This additional commitment would be consistent with the recommendations of the Stern Commission Review and other researchers.

Payroll Tax Relief or Flat Payments Financed by the Carbon Tax

Recycling the carbon-based tax revenues by shifting 90 percent of them to payroll tax relief—some $3.56 trillion of $3.96 trillion raised over 2010-2030 (in 2005 dollars, or $4.98 trillion of $5.53 trillion in current dollars)—could be accomplished by reducing the current 12.4 percent payroll tax rate or by exempting each person's initial earnings up to a certain level. The same general results also could be achieved without affecting the Social Security Trust Fund by providing people and their employers with payments equal to their benefits under a payroll tax rate cut or an exemption for initial earnings. Finally, the revenues could also be returned as flat or graduated payments to all households, since the burden of the carbon-based tax itself would be born by retirees and others outside the workforce who pay no payroll taxes.

From 2010 to 2030, carbon-based tax revenues would rise steadily as the carbon-based tax rate increases to discourage emissions and as energy

Table 9 **Revenues under a Carbon-Based Tax and Their Dedicated Uses, 2010-2030**

	2010-2030	2010-2019	2020-2030
Average Carbon Tax Rate (per mmt CO_2)			
Constant 2005 Dollars	$32.3	$22.3	$41.4
Current Dollars	$44.8	$27.3	$61.4
Carbon-Based Tax Revenues (billions)			
Constant 2005 Dollars	$3,957.2	$1,333.8	$2,623.4
Current Dollars	$5,533.6	$1,633.4	$3,900.2
Payroll Tax Relief – Total (billions)			
Constant 2005 Dollars	3,561.5	$1,200.4	$2,361.1
Current Dollars	$4,980.2	$1,470.1	$3,510.2
Payroll Tax Relief – Employer & Employee (Each)			
Constant 2005 Dollars (billions)	$1,780.7	$600.2	$1,180.5
Current Dollars (billions)	$2,490.1	$735.0	$1,755.1
R&D and Technology Deployment (billions)			
Constant 2005 Dollars	$395.7	$133.4	$262.3
Current Dollars	$553.4	$163.3	$390.0

45 During 2005-06, total tax revenues were $2.28 trillion, of which individual income was $985.6 billion, corporate income was $316.1 billion and social insurance tax was $816 billion. Source: Revenues by Major Source, 1962-2006, Congressional Budget Office; http://www.cbo.gov/budget/historical.shtml.

demand expands with economic growth. Using Social Security Administration projections of OASDI revenues, 90 percent of the new revenues would be sufficient to reduce OASDI taxes by an average of 17.5 percent over 2010-2030 (Table 10, below). If the revenues were used to reduce the current payroll tax rate of 12.2 percent of taxable wages, they could finance rate reductions averaging 2 percentage points over the 2010-2030 period—half for employees and half for the payroll taxes paid for them by their employers—rising from 1.3 percentage points in 2010 to 2.6 percentage points in 2028 and beyond.

If these revenues were used to exempt people's initial earnings from payroll taxes, they could finance exemptions rising from roughly the first $4,800 (in 2005 dollars) earned by a working person in 2010 ($5,359 in current 2010 dollars), to the first $11,116 earned in 2020 ($14,810 in current 2020 dollars) and the first $15,282 earned in 2030 ($24,900 in current

Table 10 **OASDI and Carbon-Based Tax Revenues** (in billion 2005 dollars) **and Potential Payroll Tax Rate Relief, Selected Years, 2010-2030**

Year	OASDI Revenues	Carbon-Tax Revenues for Payroll Tax Relief	Payroll Tax Relief As Share of OASDI Revenues	New Payroll Tax Rate
2010	$702.1	$75.4	10.7%	11.1%
2015	$808.0	$125.1	15.5%	10.5%
2020	$938.5	$173.8	18.5%	10.1%
2025	$1,075.7	$215.1	20.0%	9.9%
2030	$1,223.9	$253.6	20.7%	9.8%
Average	**$945.3**	**$169.5**	**17.5%**	**10.2%**

Table 11 **Payroll Tax Exemptions and Direct Payments, per Working Person, Financed by the Carbon-Based Tax, 2010-2030,** (in 2005 dollars)

Year	Working Persons (millions)	Total Payroll Tax Relief (billion)	Initial Earnings Exempt from Payroll Tax	Equivalent Direct Payment per Working Person
2010	141.8	$75.4	$4,800	$531
2011	142.9	85.3	5,492	597
2012	143.7	95.4	6,148	665
2013	144.6	105.4	6,824	729
2014	145.6	115.2	7,479	791
2015	146.7	125.1	8,137	853
2016	147.9	135.1	8,787	913
2017	149.5	144.9	9,399	969
2018	151.2	154.5	9,987	1,022
2019	152.9	163.6	10,520	1,070
2020	154.7	173.8	11,116	1,123
2021	156.4	182.3	11,593	1,166
2022	157.9	191.1	12,089	1,210
2023	159.4	199.2	12,525	1,250
2024	160.8	206.4	12,891	1,284
2025	162.2	215.1	13,372	1,326
2026	163.5	222.9	13,767	1,363
2027	164.9	231.2	14,193	1,401
2028	166.2	238.5	14,552	1,435
2029	167.5	246.0	14,912	1,469
2030	168.8	253.6	15,282	1,502
Average	**154.7**	**169.5**	**10,066**	**1,080**

2030 dollars). (Table 11, previous page) If the initial exemption applied to the payroll taxes paid by the employer as well as the employee, the levels would be half those cited: In 2005 dollars, the first $2,400 earned in 2010, rising to the initial $5,558 earned in 2020 and the first $7,645 earned in 2030. These exemptions rise sharply over this period, because carbon tax revenues should increase much faster than the number of working people. The value of these exemptions, or a payroll tax rate cut, also could be provided as a direct payment to each working person, compensating them for the additional costs of the carbon-based tax. If those payments were provided on a flat basis, they would come to $531 per working person in 2010, rising to $1,123 in 2020 and $1,502 in 2030 (in 2005 dollars, or in current dollars, $593 in 2010, $1,496 in 2020 and $2,448 in 2030). Once again, these payments could be divided between employees and their employers.

These revenues also could be distributed on a graduated basis by income, providing greater payments to lower and moderate-income people and less to higher-income people.

Finally, these revenues could be returned to every household, so as to cover people who are retired or who do not work for other reasons but, like everyone else, would pay higher energy and other prices under a carbon-based tax. If the payments were distributed directly to households, they would average $1,275 per household over the 2010-2030 period, rising from $624 per household in 2010 to $1,325 in 2020 and $1,786 in 2030 (in 2005 dollars). These revenues also could be divided between households and businesses. (Table 12, below)

Table 12 **Payments to Each Household Financed by the Carbon-Based Tax Package, 2010-2030** (in 2005 dollars)

Year	Households (millions)	Total Payroll Tax Relief (billions)	Payments per Household	Payments per Household, with Half to Business
2010	120.7	$75.4	$624	$312
2011	121.8	85.3	701	$351
2012	122.8	95.4	777	$389
2013	123.9	105.4	851	$426
2014	124.9	115.2	923	$462
2015	126.0	125.1	993	$497
2016	127.0	135.1	1,063	$532
2017	128.0	144.9	1,131	$566
2018	129.1	154.5	1,197	$599
2019	130.1	163.6	1,257	$629
2020	131.2	173.8	1,325	$663
2021	132.2	182.3	1,379	$690
2022	133.3	191.1	1,434	$717
2023	134.3	199.2	1,483	$742
2024	135.4	206.4	1,525	$763
2025	136.5	215.1	1,576	$788
2026	137.6	222.9	1,620	$810
2027	138.7	231.2	1,667	$834
2028	139.8	238.5	1,707	$854
2029	140.9	246.0	1,746	$873
2030	142.0	253.6	1,786	$893
Average	**131.2**	**$169.5**	**$1,275**	**$638**

Returning the revenues from the carbon-based tax as payroll tax relief or household rebates is intended to achieve meaningful progress in climate change without overly burdening most Americans or impairing economic growth. The NEMS model found, as expected and intended, that the new charges would substantially raise the prices that businesses and households would pay for carbon-intensive fuels. The price of coal, the most carbon-intensive energy source, is projected to increase more than threefold, from an average of $1.67 per million Btu in 2005-2007 to $3.70 per million BTU over 2010-2019 and $5.40 per million BTU over 2020-2030. Gasoline prices would rise about 7 percent more under a carbon-based tax than under business as usual over 2010 to 2019, and by about 14 percent more over 2020-2030. The tax also would raise electricity prices by 14 percent in the first decade and by nearly 25 percent in the second decade. (Table 13, below)

Without a provision to recycle or rebate the revenues from the carbon-based tax, these price increases will directly affect Americans' ability to purchase and use other goods and services. The Bureau of Labor Statistics reports that the average U.S. household spends more on energy than on any other category except housing: In 2001, 11.2 percent of an average household's total spending went directly for energy (6.9 percent for residential utilities and 4.3 percent for gasoline), compared to 19 percent for shelter, 7.1 percent for food, and 10.4 percent for pensions and Social Security.[46] Using NEMS projections under current policies and trends, we estimate that the average household will spend an average of $1,803 per year (in 2005 dollars) to heat, cool, light and operate their homes over 2010-2030. The proposed carbon-based tax package will raise the price of the fuels used for residential energy based on their carbon intensity, and thus would both reduce modestly the overall demand for residential energy and change the mix of fuels used to provide it. Taken together, these changes are projected to increase the cost of residential energy use for an average-income household by $239 per year over 2010-2030 (in 2005 dollars), rising from an additional $83 per household in 2010 to $238 in 2020 and $376 in 2030. Economists also often calculate these effects in a second way, comparing the cost against no carbon-based tax but the use levels expected with the tax, with the cost at those use levels with the carbon-based tax. This provides insight into the cost of the tax if the quantity of energy used were held constant. This adjusted cost of the carbon tax for a typical household's residential energy averages $280 per year over 2010-2030, rising from $92 in 2010 to $278 in 2020 and $444 in 2030. (Table 14, next page)

Over the 2010-2030 period, the NEMS model forecasts that residential energy use will account for 15.4 percent of total U.S. energy use (Table A.20, Appendix). If the effects of the carbon-based tax on other energy uses by commercial and industrial businesses, as well as transportation, are all passed along to consumers, the total additional burden of

Table 13 **U.S. Domestic Energy Prices, 2005-2030, per Million BTU**
(in 2005 dollars)

	2005-2007	2010-2019		2020-2030	
		Business As Usual	Carbon-Based Tax	Business As Usual	Carbon-Based Tax
Liquefied Petroleum Gas	18.63	17.47	18.24	17.92	19.44
Motor Gasoline	20.38	16.90	18.14	17.43	19.85
Jet Fuel	13.69	10.17	11.63	11.16	13.94
Distillate Fuel Oil	17.64	14.40	15.92	15.16	18.09
Natural Gas	9.17	7.26	8.32	7.66	9.70
Metallurgical Coal	3.21	2.82	5.40	2.82	7.35
Principal Coal	1.67	1.65	3.70	1.66	5.41
Electricity	24.15	22.87	26.08	23.37	29.12

46 BLS, "Consumer Expenditures in 2005," U.S. Bureau of Labor; http://www.bls.gov/cex/csxann05.pdf.

Table 14 **Average Household's Residential Energy Expenditures, Business As Usual Versus the Carbon-Based Tax Package, 2010-2030** (in 2005 dollars)

Year	Business As Usual	With a Carbon-Based Tax	Cost of the Carbon-Based Tax	Reduced Use and No Carbon Tax	Cost of the Tax (adjusted)
2010	$1,820	$1,903	$83	$1,812	$92
2011	1,783	1,922	139	1,766	156
2012	1,775	1,918	143	1,752	166
2013	1,759	1,909	150	1,732	177
2014	1,755	1,919	165	1,726	194
2015	1,757	1,934	177	1,725	209
2016	1,772	1,962	190	1,739	223
2017	1,784	1,982	198	1,750	233
2018	1,789	1,989	200	1,753	236
2019	1,791	2,004	213	1,753	251
2020	1,799	2,036	238	1,758	278
2021	1,794	2,045	251	1,750	295
2022	1,807	2,069	261	1,761	308
2023	1,817	2,079	261	1,769	309
2024	1,830	2,102	272	1,780	322
2025	1,822	2,124	303	1,769	356
2026	1,828	2,146	318	1,771	375
2027	1,834	2,178	344	1,774	405
2028	1,845	2,206	361	1,781	425
2029	1,847	2,217	369	1,781	436
2030	1,851	2,228	376	1,783	444
Average	**$1,803**	**$2,042**	**$239**	**$1,761**	**$280**

the tax on American households can be estimated roughly by using the ratio of the cost of the tax for residential use and the other uses of energy. By this reasoning, a carbon-based tax that would substantially mitigate the risks of climate change could raise the direct, energy-related costs of an average-income household by an average of $1,563 per year over 2010-2030, rising from $524 in 2010 to $1,536 in 2020 and $2,555 in 2030 (in 2005 dollars). (Table 15, next page) Those totals include an average-income household's tax-related costs to heat, cool, light and operate their home, drive their automobiles and take trains, buses and airplanes, and absorb the carbon-based taxes paid by the businesses producing all of the other goods and services that an average household buys and uses.

Returning most of the revenues from the carbon-based tax in payroll tax relief or equivalent payments to households could offset all or most of these direct costs for most Americans. Returning 90 percent of the revenues as flat payments for all households would provide an average of $1,275 per year, per household over 2010-2030 (in 2005 dollars), or 82 percent of the direct, additional carbon-based, tax-related costs for an average-income household. In practice, a flat $1,275 payment should more than offset all of the direct, tax-related costs for most American households. One reason is that the NEMS model uses as its measure the average or "mean" income household, an income level considerably above the midpoint or median in the income distribution, because more of total U.S. national income is concentrated in relatively smaller numbers of households at the upper end. In 2006, for example, when the median household income was $48,201, the average-income household earned $66,570, or some 38 percent more than the median-income household. As a result, nearly 68 percent of households have incomes below the "average income" used by the NEMS model and EIA reports. Furthermore, the estimate that the carbon-based tax program will impose additional direct costs on the average-income household of $1,563 per year probably overstates what the real-world costs will be for most households. Some of the costs of the tax on some businesses will not be passed along to consumers, because producers in intensely competitive industries such as airlines or computer hardware will force each other to absorb some of their own carbon tax-related costs.

This analysis shows that the United States could apply carbon-based charges of sufficient dimensions to reduce CO_2 emissions to a path that should produce concentration levels safe for the climate over the long term, and without imposing significant direct costs on most Americans. By raising the price of fuels based on their carbon intensity, and the price of everything else based on the carbon intensity of their production and distribution, consumers and businesses will tend to favor cleaner forms of both energy and other goods and services. As hundreds of millions of people make those choices across the economy, CO_2 emissions would fall significantly with declining purchases and use of more carbon-intensive fuels, materials, goods and services. The direct cost to Americans and U.S. businesses is the tax itself, which is largely offset by recycling its revenues.

Table 15 **Direct Annual Cost of the Carbon-Based Tax Package for an Average-Income U.S. Household, 2010-2030** (in 2005 dollars)

Year	Additional Cost per Household of Delivered Residential Energy	Residential Share of Total Delivered Energy	Estimated Additional Cost per Household All Energy Consumed
2010	$83	15.9%	$524
2011	139	15.9	876
2012	143	15.9	902
2013	150	15.8	952
2014	165	15.8	1,045
2015	177	15.7	1,127
2016	190	15.7	1,207
2017	198	15.6	1,266
2018	200	15.6	1,283
2019	213	15.5	1,373
2020	238	15.5	1,536
2021	251	15.4	1,634
2022	261	15.3	1,709
2023	261	15.2	1,715
2024	272	15.2	1,790
2025	303	15.1	2,002
2026	318	15.0	2,116
2027	344	15.0	2,302
2028	361	14.9	2,418
2029	369	14.8	2,494
2030	376	14.7	2,555
Average	**$239**	**15.4**	**$1,563**

The final set of questions involves the indirect effects of this strategy on the U.S. economy and most Americans. Reducing emissions sufficiently to put the United States on a sustainable path for climate change will not happen for free. Even so, the tax package avoids the largest, potential, adverse economic effects by returning most of its revenues in tax relief, which would largely maintain overall demand even as the tax claims an average of $188.4 billion a year (in 2005 dollars). This approach also should cost Americans and the U.S. economy less than the alternative approaches to climate change, not only because it offsets most of the impact of higher energy prices on incomes and demand, but also because many economists have found that a tax-based approach imposes lower costs on the economy's efficiency than cap and trade or traditional regulation.

The result is that the carbon-based tax program should impose very modest burdens on the overall economy. The NEMS model found that this tax-based strategy would shave the economy's growth rate, on average, by about one-half of one percent a year. (Table 16, below) The nation's GDP would expand from $14.39 trillion in 2010 to $19.2 trillion, or 33.4 percent, under the carbon-based tax program, compared to an increase from $14.42 trillion in 2010 to $19.26 trillion in 2020, or 33.6 percent,under business as usual (in 2005 dollars). After the first decade of the program, therefore, the difference in overall growth would be two-tenths of one percent. Over the next decade, 2020-2030, the economy is forecast to grow 31.0 percent with the carbon-based tax package, compared to 31.7 percent under business as usual, a difference of less than three-fourths of one percent. After 20 years, U.S. GDP would be $214 billion smaller with the carbon-based tax package than under business as usual, a difference of between eight-tenths and nine-tenths of one percent.

Because preventing adverse climate changes is not strictly an economic goal, but a social and humane one, achieving it inescapably will involve economic costs. The NEMS model's results substantially reflect what economists call the particular "demand elasticity" of energy: If a carbon-based tax (or tight energy supplies, for that matter) raises the price of energy by 10 percent, demand for energy will decline, but by less than 10 percent. The result is that people and businesses have to spend more of their resources on energy and are left with less to spend or invest in everything else. That explains why the NEMS model finds that consumption and investment both would grow at marginally lower rates under the carbon-based tax program than without it. (Tables A.11-A.13, Appendix) If climate scientists could say what the precise dimensions of climate change will be in 2030 or 2050 under current conditions and trends, the costs of those changes could be assessed and weighed against the costs of preventing them. Since those dimensions and calculations remain beyond our knowledge, the NEMS model and other macroeconomic forecasting models cannot ascribe any precise economic value to reducing CO_2 emissions and averting climate changes, so all that is left to measure are the costs.

Slightly slower growth in consumption and investment would have some small effects on jobs and unemployment, and the higher energy prices will mean a little more inflation. Under the proposed carbon-based tax package, however, these costs would be very small, especially considered as part of a serious strategy for addressing climate change. The

Table 16 **U.S. GDP with the Carbon-Based Tax Package Versus Business As Usual, Selected Years, 2010-2030,** (in billion 2005 dollars)

	Business As Usual	Carbon-Based Tax	Difference	% Difference
2010	$12,786	$12,766	$20	0.16%
2020	$17,079	$17,029	$50	0.29%
2030	$22,489	$22,300	$189	0.84%
Gain, 2010-2019	+ $4,140	+ $4,101	$39	0.94%
Gain, 2020-2030	+ $5,930	+ $5,780	$150	2.53%
Gain, 2010-2030	+ $10,007	+ $9,881	$189	1.89%

NEMS model found that over 2010-2030, U.S. unemployment would average about one-tenth of one percent higher under the new tax package than under the business-as-usual scenario; and by 2030, the total U.S. workforce would be about one-quarter of one percent smaller. (Table 17, below) Half of that small difference would be concentrated in energy-intensive manufacturing jobs, which the NEMS model estimates would fall to 12.3 million jobs in 2030 under a carbon-based tax strategy, compared to 12.5 million jobs under business as usual.

Similarly, while a serious carbon-based tax program has significant and intended effects on energy prices, its effects on overall inflation would be modest: Over 2010-2020, total inflation is projected to be three-tenths of one percent higher under the carbon-based tax package than under business as usual (Table 18, below). Although the carbon-based tax rate rises over the following decade, the difference in overall inflation is still only 1.1 percentage points. One reason for the small inflationary impact is that without the carbon-based tax, energy prices are expected to rise rapidly in the decade 2020-2030 as worldwide demand expands faster than worldwide supply, while the new tax package slows U.S. demand for energy by applying its charges. In the end, a good that costs $10.00 today would cost $11.84 in 2019 and $15.20 in 2030 with the carbon-based tax program, compared to $11.81 in 2019 and $14.91 in 2030 under business as usual.

A system of cap and trade would almost certainly extract greater costs from the economy. As under a carbon-based tax, a cap-and-trade program would raise the price of energy (and with greater volatility in those prices) and therefore also would tend to marginally slow the growth of consumption, investment, the labor force and GDP, and marginally increase unemployment and inflation. But a cap-and-trade system would be less efficient than the carbon-based tax approach and does not recycle its revenues, and therefore it should entail considerably greater costs to the economy. Any serious climate change strategy, whether it involves tradable permits, strict regulations or carbon-based taxes, also cannot

Table 17 **Changes in Unemployment and the Labor Force, Carbon-Based Tax Package Versus Business As Usual, 2010-2030**

	Business As Usual		Carbon-Based Tax		Difference	
	Jobless Rate	Labor Force (millions)	Jobless Rate	Labor Force (millions)	Jobless Rate (percent. pts.)	Labor Force
2010	4.8%	157.5	4.9%	157.4	0.1	18,000
2020	4.5%	167.0	4.5%	166.9	0.0	98,000
2030	4.7%	180.4	4.9%	180.1	0.2	317,000
2010-2019	4.8%	161.8	5.0%	161.7	0.2	149,000
2020-2030	4.5%	173.1	4.6%	172.9	0.1	207,000
2010-2030	4.7%	167.7	4.8%	167.6	0.1	179,000

Table 18 **The Consumer Price Index and the Energy Price Index, Carbon-Based Tax Package Versus Business As Usual, 2010-2030**

	Business As Usual		Carbon-Based Tax		Difference (percentage points)	
	All Urban	Energy	All Urban	Energy	All Urban	Energy
2010	1.6%	0.0%	2.1%	4.5%	0.5 pts.	4.5
2020	1.8%	0.0%	2.1%	2.5%	0.3	2.5
2030	2.2%	3.4%	2.2%	2.9%	0.0	-0.5
2010-2019	18.1%	11.5%	18.4%	18.6%	0.3	7.1
2020-2030	23.9%	31.2%	25.0%	38.5%	1.1	7.3
2010-2030	49.1%	46.2%	51.2%	68.4%	2.1	22.2

Table 19 **Average Household Income, Carbon-Based Tax Package Versus Business As Usual, 2010-2030** (in 2005 dollars)

Year	Household Income – Business As Usual	Household Income – Carbon-Based Tax	Difference	Percent Difference
2010	$71,184	$70,843	$341	0.5%
2011	72,769	71,959	810	1.1
2012	74,241	73,126	1,115	1.5
2013	75,628	74,482	1,147	1.5
2014	77,295	76,097	1,198	1.5
2015	79,026	77,810	1,216	1.5
2016	80,805	79,674	1,131	1.4
2017	82,729	81,645	1,084	1.3
2018	84,738	83,671	1,067	1.3
2019	86,788	85,686	1,102	1.3
2020	89,106	87,863	1,243	1.4
2021	91,303	89,976	1,327	1.5
2022	93,406	91,962	1,444	1.5
2023	95,556	94,032	1,524	1.6
2024	97,681	96,032	1,649	1.7
2025	99,878	98,111	1,767	1.8
2026	102,158	100,244	1,914	1.9
2027	104,357	102,322	2,035	2.0
2028	106,590	104,406	2,184	2.0
2029	108,829	106,513	2,316	2.1
2030	110,913	108,478	2,435	2.2
Average	**$89,761**	**$88,330**	**$1,431**	**1.6%**

avoid the economic costs of what it aims to achieve, namely, the replacement or retooling of energy- or carbon-intensive technologies and other equipment, materials and processes, factories and offices, automobiles and all other transport, and countless other business and personal goods. Many of these costs also would be recouped over the long term, however, as the retooling and replacement process raised the economy's overall energy efficiency.

When all of these small, indirect effects are considered together, their impact on the average-income American household is also modest under a carbon-based tax program. The NEMS projections show that an average-income household would earn $70,846 in 2010 under the new tax package, compared to $71,184 under business as usual (in 2005 dollars), a difference of one-half of one percent (Table 19, above). By 2030, with the United States on a path for reducing CO_2 emissions that would substantially mitigate the long-term risks to the global climate, the cost of all of the indirect effects of following that path for 20 years would come to 1.6 percent of the average American household's income.

Conclusion

The need to address the risks of climate change is clear and pressing. Without taking serious steps to reduce emissions of CO_2 and other greenhouse gases, their concentrations in the atmosphere will reach levels in a few decades that will change the world's weather, and the patterns of people's economic and social lives across the globe. The primary sources of the rising atmospheric concentrations of CO_2 and other GHG are the carbon-based fossil fuels used to power the economies of every country, so serious measures to reduce the growth of those emissions could have far-reaching economic and social effects.

This study has examined a strategy that promises to reduce those emissions to a path that should be able to sustain the world's climate, at comparatively modest costs to the U.S. economy and to American households. This strategy would apply a new tax to the use of energy based on its carbon content and return 90 percent of the revenues in tax relief to the people and businesses using the energy and paying the tax, and use 10 percent of those revenues for additional investments in energy and climate-related research and development, and in the deployment of climate-friendly fuels and technologies.

By 2030, these shifts would drive down U.S. CO_2 emissions by about 30 percent, compared to what they would be under the EIA's business-as-usual scenario, creating a new emissions path for the United States which, relative to its role in global emissions over the next several decades, would move toward a stabilization path of atmospheric CO_2 concentrations at safe levels of 450-550 ppmv and avert the serious risks of climate change.

The package analyzed here would apply a new tax that would rise gradually from $14 per metric ton of CO_2 in 2010 to $50 per metric ton in 2030. We use the NEMS modeling system employed by the U.S. Department of Energy to project the various effects of this proposed new tax, and its accompanying tax rebates and public investments. The NEMS model found that this tax-based strategy would steadily move businesses and households to prefer less carbon-intensive fuels, to use less energy-intensive technologies and products, and to conduct their businesses and lives in other ways that use less energy generally and especially less carbon-intensive energy. By 2030, these shifts would drive down U.S. CO_2 emissions by about 30 percent, compared to what they would be under the EIA's business-as-usual scenario, creating a new emissions path for the United States which, relative to its role in global emissions over the next several decades, would move toward a stabilization path of atmospheric CO_2 concentrations at safe levels of 450-550 ppmv and avert the serious risks of climate change.

Every approach to climate change necessarily will involve higher energy prices. By capturing those price increases in a tax, this program can rebate its revenues and sharply reduce both the direct costs of the tax for most businesses and people, as well as most of the indirect costs. For an average-income American household, the program would increase by $1,563 per year, over 2010-2030, the costs to heat, cool and operate a home, drive cars and take trains, airplanes and buses, and produce and distribute all the goods and services that an average household consumes. This estimate probably overstates the burden, because some businesses will be unable to pass along all of their additional energy costs, and the tax will likely promote energy-related innovations in order to reduce that burden. Dedicating 90 percent of the potential $4 trillion in revenues collected over 2010-2030 under this carbon-based tax approach for tax relief would be sufficient to reduce the payroll tax rate for workers and businesses by two percentage points, exempt from payroll tax a worker's initial $10,066 in earnings (or $5,033 from the payroll taxes of each worker and his or her employer), or provide every working person a rebate payment of $1,080 each. If these revenues were rebated as flat payments to all U.S. households, they would average $1,275 per year, per household from 2010-2030, or 83 percent of the direct cost of the tax for an average-income household. These payments would offset the direct, tax-related costs for most households, however, since roughly two-thirds of

American households have incomes below that "average." (In 2006, the average household income was $66,570, or nearly 40 percent higher than the median household income of $48,201.)

Coupled with the incentives from the carbon-based tax itself to develop more climate-friendly fuels, technologies, materials and products, the large increases for R&D and technology deployment could produce advances that would reduce emissions even more rapidly and sharply, and at lower costs to the economy, and to American businesses and households.

Every serious approach to climate change also will involve indirect costs for the economy, as higher energy prices reduce consumption and investment for everything else, and as utilities, businesses and households retool or replace their carbon-intensive technologies, equipment, automobiles and appliances to use alternative fuels and achieve higher energy efficiency. After 20 years, U.S. GDP in 2030 would be $22.3 trillion with the carbon-based tax program, or about eight-tenths of one percent less than the $22.5 trillion forecast for GDP in 2030 under business as usual. Unemployment over 2010-2030 would average one-tenth of one percent higher with the carbon-based tax package than under business as usual. The overall inflation rate would be an average of 2.1 percent higher, almost all of which would directly reflect the impact of the tax on energy prices.

All told, the indirect economic effects of achieving this path to preserve the world's climate would have a very modest impact on the prosperity of Americans: Over 2010-2030, an average-income household would earn an average of $88,330 per year under the carbon-based tax program, compared to an average of $89,761 under the business-as-usual scenario. Moreover, these costs could be considerably less, because the program also dedicates 10 percent of its revenues to energy and climate change-related R&D and technology deployment, or an average of nearly $19 billion per year over 2010-2030. Coupled with the incentives from the carbon-based tax itself to develop more climate-friendly fuels, technologies, materials and products, the large increases for R&D and technology deployment could produce advances that would reduce emissions even more rapidly and sharply, and at lower costs to the economy, and to American businesses and households. Along with the model for a carbon-based tax strategy, these climate-friendly fuels and technologies could be provided or transferred in a variety of ways to the fast-growing developing nations that will play major roles in worldwide CO_2 and GHG emissions in coming decades, as essential features of a genuine global strategy to avert destructive climate changes.

With this approach, the United States could do its part to put the world on energy and emissions paths that can preserve the global climate, at very modest costs to the U.S. economy, most of its businesses and to the American people.

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Appendix

List of Tables

Table A.1. Carbon-Based Tax Program: Key Assumptions for Payroll Tax Cut Scenario, 2010-2030

Year	**Carbon-Based Tax Rate** (2005 dollars per metric ton of CO_2)	**Carbon-Based Tax Rate** (current dollars per metric ton of CO_2)	**Share of Carbon-Based Tax Revenues for Payroll Tax Cut for Employers and Employees**	**Share of Revenues for R&D and Technology Deployment**
2010	$14.0	$15.7	90%	10%
2011	15.9	18.1	90%	10%
2012	17.7	20.5	90%	10%
2013	19.5	23.1	90%	10%
2014	21.4	25.6	90%	10%
2015	23.2	28.3	90%	10%
2016	25.0	31.0	90%	10%
2017	26.3	33.9	90%	10%
2018	28.7	36.8	90%	10%
2019	30.5	39.9	90%	10%
2020	32.3	43.1	90%	10%
2021	34.1	46.4	90%	10%
2022	36.0	49.9	90%	10%
2023	37.8	53.4	90%	10%
2024	39.6	57.2	90%	10%
2025	41.5	61.1	45%	10%
2026	43.3	65.0	90%	10%
2027	45.1	69.2	90%	10%
2028	46.9	73.5	90%	10%
2029	48.8	77.9	90%	10%
2030	50.6	82.4	90%	10%

Table A.2.

Carbon Dioxide Emissions: Business-As-Usual Scenario Versus Carbon-Based Tax Package, Selected Years, U.S. Household, 1990-2030 (in millions of metric tons of CO_2 equivalent)

Year	Business As Usual	Carbon-Based Tax Package	Difference (%)
1990	4,989	–	–
1995	5,327	–	–
2000	5,664	–	–
2005	5,945	–	–
2010	6,214	5,962	-4.0%
2011	6,294	5,972	-5.1%
2012	6,378	5,993	-6.0%
2013	6,437	6,002	-6.8%
2014	6,512	5,998	-7.9%
2015	6,570	5,998	-8.7%
2016	6,637	6,003	-9.6%
2017	6,691	6,001	-10.3%
2018	6,743	5,993	-11.1%
2019	6,817	5,966	-12.5%
2020	6,920	5,977	-13.6%
2021	7,010	5,937	-15.3%
2022	7,104	5,907	-16.8%
2023	7,198	5,858	-18.6%
2024	7,296	5,792	-20.6%
2025	7,391	5,769	-21.9%
2026	7,513	5,726	-23.8%
2027	7,613	5,697	-25.2%
2028	7,715	5,650	-26.8%
2029	7,811	5,608	-28.2%
2030	7,919	5,572	-29.6%

Data from 1990-2006 are actual.

Table A.3. Carbon-Based Tax Package: Revenues and Their Dedicated Uses under Payroll Tax Cut Scenario, 2010-2030 (in 2005 dollars)

Year	Carbon-Based Tax Rate ($ per metric ton of CO_2)	Carbon-Based Tax Rate ($ per metric ton of carbon	Carbon-Based Tax Revenues ($ billions)	Payroll Tax Relief for Employers ($ billions)	Payroll Tax Relief for Employees ($ billions)	R&D/ Technology Deployment ($ billions)
2010	14.0	51.5	83,762	37,693	37,693	8,376
2011	15.9	58.2	94,815	42,667	42,667	9,481
2012	17.7	64.9	106,087	47,739	47,739	10,609
2013	19.5	71.6	117,205	52,742	52,742	11,720
2014	21.4	78.3	128,089	57,640	57,640	12,809
2015	23.2	85.0	139,031	62,564	62,564	13,903
2016	25.0	91.7	150,116	67,552	67,552	15,012
2017	26.8	98.4	161,034	72,465	72,465	16,103
2018	28.7	105.1	171,765	77,294	77,294	17,177
2019	30.5	111.8	181,899	81,854	81,854	18,190
2020	32.3	118.5	193,149	86,917	86,917	19,315
2021	34.1	125.2	202,682	91,207	91,207	20,268
2022	36.0	131.9	212,464	95,609	95,609	21,246
2023	37.8	138.6	221,404	99,632	99,632	22,140
2024	39.6	145.3	229,473	103,263	103,263	22,947
2025	41.4	152.0	239,110	107,599	107,599	23,911
2026	43.3	158.7	247,759	111,492	111,492	24,776
2027	45.1	165.4	256,944	115,625	115,625	25,694
2028	46.9	172.1	265,128	119,308	119,308	26,513
2029	48.8	178.8	273,405	123,032	123,032	27,340
2030	50.6	185.5	281,844	126,830	126,830	28,184
Total	–	–	**3,957,162**	**1,780,723**	**1,780,723**	**395,716**
Average 2010-30	**32.3**	**118.5**	**188,436**	**84,796**	**84,796**	**18,844**
Average 2010-19	**22.3**	**81.7**	**133,380**	**60,021**	**60,021**	**13,338**
Average 2020-30	**41.4**	**152.0**	**238,487**	**107,319**	**107,319**	**23,849**

Table A.4. Carbon-Based Tax Package: Revenues and Their Dedicated Uses under Payroll Tax Cut Scenario, 2010-2030 (in current dollars)

Year	Carbon-Based Tax Rate ($ per metric ton of CO_2)	Carbon-Based Tax Rate ($ per metric ton of carbon	Carbon-Based Tax Revenues ($ billions)	Payroll Tax Relief for Employers ($ billions)	Payroll Tax Relief for Employees ($ billions)	R&D/ Technology Deployment ($ billions)
2010	15.7	57.5	93,484	42,068	42,068	9,348
2011	18.1	66.3	107,919	48,564	48,564	10,792
2012	20.5	75.3	123,025	55,361	55,361	12,303
2013	23.1	84.5	138,305	62,237	62,237	13,831
2014	25.6	93.9	153,550	69,097	69,097	15,355
2015	28.3	103.6	169,460	76,257	76,257	16,946
2016	31.0	113.8	186,170	83,777	83,777	18,617
2017	33.9	124.2	203,168	91,425	91,425	20,317
2018	36.8	135.0	220,505	99,227	99,227	22,051
2019	39.9	146.2	237,839	107,028	107,028	23,784
2020	43.1	157.9	257,227	115,752	115,752	25,723
2021	46.4	170.0	275,190	123,835	123,835	27,519
2022	49.9	182.9	294,492	132,521	132,521	29,449
2023	53.4	196.0	312,964	140,834	140,834	31,296
2024	57.2	209.7	331,065	148,979	148,979	33,106
2025	61.1	223.9	352,121	158,454	158,454	35,212
2026	65.0	238.5	372,276	167,524	167,524	37,228
2027	69.2	253.7	394,080	177,336	177,336	39,408
2028	73.5	269.5	415,104	186,797	186,797	41,510
2029	77.9	285.6	436,588	196,465	196,465	43,659
2030	82.4	302.2	459,043	206,569	206,569	45,904
Total	–	–	**5,533,576**	**2,490,109**	**2,490,109**	**553,358**
Average 2010-30	**45.3**	**166.2**	**263,504**	**118,577**	**118,577**	**26,350**
Average 2010-19	**27.3**	**100.0**	**163,343**	**73,504**	**73,504**	**16,334**
Average 2020-30	**61.7**	**226.3**	**354,559**	**159,552**	**159,552**	**35,456**

Table A.5.

Selected Energy Prices under Business-As-Usual Scenario, 2005-2030 (per million BTU, in 2005 dollars)

Year	Liquefied Petroleum Gas	Motor Gas	Jet Fuel	Residential Fuel Oil	Natural Gas	Principal Coal	Electricity
2005	$17.5	$18.6	$13.1	$16.2	$6.6	$3.1	$1.6
2010	18.0	18.4	10.8	15.6	7.6	3.1	1.7
2011	17.5	17.4	10.4	14.9	7.2	3.0	1.7
2012	17.4	17.0	10.0	14.3	6.8	2.9	1.7
2013	17.3	17.0	10.0	14.2	6.4	2.8	1.7
2014	17.3	16.1	9.7	13.7	6.5	2.8	1.6
2015	17.3	16.3	9.8	13.9	6.5	2.7	1.6
2016	17.4	16.5	10.0	14.2	6.5	2.7	1.6
2017	17.5	16.3	10.0	14.1	6.6	2.7	1.6
2018	17.6	16.7	10.2	14.3	6.7	2.7	1.6
2019	17.6	17.2	10.7	14.7	6.9	2.7	1.6
2020	17.6	16.5	10.4	14.4	6.9	2.8	1.6
2021	17.6	16.7	10.6	14.6	7.1	2.8	1.6
2022	17.7	17.2	10.9	14.9	7.1	2.8	1.6
2023	17.8	17.1	10.9	14.7	7.2	2.8	1.6
2024	17.9	17.3	11.0	14.9	7.4	2.8	1.6
2025	17.9	17.8	11.2	15.3	7.5	2.8	1.7
2026	18.0	17.4	11.1	15.0	7.5	2.8	1.7
2027	18.0	17.6	11.3	15.4	7.6	2.8	1.7
2028	18.1	17.9	11.5	15.6	7.7	2.9	1.7
2029	18.2	18.0	11.8	15.7	7.7	2.9	1.7
2030	18.3	18.4	12.0	16.2	7.9	2.9	1.7
Average 2005-07	**$18.6**	**$20.4**	**$13.7**	**$17.6**	**$7.6**	**$3.2**	**$1.7**
Average 2010-30	**$17.7**	**$17.2**	**$10.7**	**$14.8**	**$7.1**	**$2.8**	**$1.7**
Average 2010-19	**$17.5**	**$16.9**	**$10.2**	**$14.4**	**$6.8**	**$2.8**	**$1.7**
Average 2020-30	**$17.9**	**$17.4**	**$11.2**	**$15.2**	**$7.4**	**$2.8**	**$1.7**

Table A.6. **Selected Energy Prices under Carbon-Based Tax Package, 2010-2030**
(per million BTU, in 2005 dollars)

Year	Liquefied Petroleum Gas	Motor Gas	Jet Fuel	Residential Fuel Oil	Natural Gas	Principal Coal	Electricity
2010	18.5	19.2	11.8	16.6	9.4	4.7	3.0
2011	18.1	18.4	11.5	16.0	9.2	4.8	3.2
2012	18.0	18.1	11.3	15.6	9.0	4.9	3.3
2013	18.0	18.1	11.3	15.6	8.5	4.9	3.4
2014	18.1	17.5	11.2	15.3	8.7	5.4	3.6
2015	18.1	17.7	11.4	15.6	9.0	5.5	3.8
2016	18.2	18.0	11.7	15.8	9.2	5.7	3.9
2017	18.4	17.8	11.8	15.9	9.5	5.9	4.1
2018	18.4	18.1	12.0	16.2	9.7	6.1	4.3
2019	18.6	18.5	12.4	16.6	9.9	6.3	4.4
2020	18.7	18.5	12.5	16.7	10.2	6.4	4.6
2021	18.8	18.8	12.8	16.9	10.4	6.6	4.7
2022	19.0	19.4	13.3	17.5	10.7	6.8	4.9
2023	19.0	19.2	13.2	17.2	10.9	7.0	5.1
2024	19.2	19.5	13.6	17.7	11.2	7.2	5.2
2025	19.4	19.9	14.0	18.1	11.5	7.3	5.4
2026	19.6	19.9	14.1	18.2	11.8	7.5	5.6
2027	19.8	20.3	14.5	18.6	12.1	7.7	5.7
2028	20.0	20.8	14.9	19.2	12.3	7.9	5.9
2029	20.1	20.9	15.0	19.2	12.6	8.1	6.1
2030	20.1	21.3	15.4	19.7	12.8	8.3	6.3
Average 2010-2030	**18.9**	**19.0**	**12.8**	**17.1**	**10.4**	**6.4**	**4.6**
Average 2010-2019	**18.2**	**18.1**	**11.6**	**15.9**	**9.2**	**5.4**	**3.7**
Average 2020-2030	**19.4**	**19.8**	**13.9**	**18.1**	**11.5**	**7.3**	**5.4**

Table A.7. Percentage Differences in Selected U.S. Energy Prices, Carbon-Based Tax Package Versus Business-As-Usual Scenario, 2010-2030 (%)

Year	Liquefied Petroleum Gas	Motor Gas	Jet Fuel	Residential Fuel Oil	Natural Gas	Principal Coal	Electricity
2010	2.8%	4.6%	8.6%	6.2%	23.6%	51.2%	74.0%
2011	3.4%	5.7%	10.3%	7.4%	26.8%	59.8%	86.2%
2012	3.6%	6.5%	12.0%	8.8%	30.9%	67.6%	97.0%
2013	4.4%	6.1%	13.0%	9.8%	33.7%	75.4%	108.3%
2014	4.6%	8.2%	16.0%	11.6%	34.8%	94.5%	119.2%
2015	4.9%	8.4%	16.6%	11.9%	38.8%	101.9%	130.6%
2016	5.0%	8.9%	16.6%	11.5%	41.6%	111.0%	141.9%
2017	5.0%	8.9%	17.5%	13.1%	43.2%	117.1%	153.3%
2018	5.1%	8.7%	17.3%	13.0%	44.7%	122.7%	165.2%
2019	5.7%	8.0%	16.5%	12.9%	45.0%	127.4%	174.8%
2020	6.5%	12.3%	20.3%	15.8%	46.9%	133.0%	185.3%
2021	6.9%	12.8%	21.1%	16.1%	47.5%	137.9%	194.9%
2022	7.0%	12.5%	22.0%	17.7%	49.8%	143.5%	203.2%
2023	6.7%	12.3%	21.6%	16.4%	51.6%	149.1%	211.0%
2024	7.2%	12.5%	23.5%	18.8%	52.1%	154.4%	218.3%
2025	8.9%	12.1%	24.9%	18.3%	53.8%	159.9%	225.8%
2026	9.1%	14.7%	27.3%	21.2%	56.2%	165.7%	232.9%
2027	9.9%	14.9%	28.0%	21.2%	58.7%	171.2%	240.5%
2028	10.0%	15.9%	29.3%	22.9%	59.7%	176.7%	248.5%
2029	10.5%	16.1%	27.6%	21.7%	62.4%	181.9%	256.1%
2030	10.0%	16.1%	27.7%	22.0%	62.4%	187.4%	263.3%
Average 2010-2030	**6.6%**	**10.8%**	**20.2%**	**15.3%**	**46.3%**	**127.7%**	**177.7%**
Average 2010-2019	**4.4%**	**7.3%**	**14.4%**	**10.6%**	**36.1%**	**91.8%**	**124.2%**
Average 2020-2030	**8.5%**	**13.9%**	**25.0%**	**19.4%**	**54.8%**	**160.3%**	**226.0%**

Table A.8.

U.S. Energy Consumption by Fuel, Business-As-Usual Scenario, 2005-2030
(in quadrillion BTU)

Year	Total	Liquid	Natural Gas	Coal	Nuclear	Biofuels	Renewables
2005	100.3	40.7	22.7	22.9	8.1	2.4	0.8
2010	106.2	41.7	24.5	24.3	8.3	3.0	1.2
2011	107.4	42.3	24.8	24.6	8.4	3.1	1.2
2012	108.6	42.8	25.2	24.9	8.4	3.1	1.2
2013	109.6	43.3	25.5	25.0	8.4	3.2	1.2
2014	110.7	43.8	25.7	25.3	8.4	3.2	1.2
2015	111.9	44.1	26.1	25.4	8.5	3.4	1.3
2016	113.1	44.6	26.3	25.7	8.7	3.5	1.3
2017	114.0	45.0	26.2	26.0	8.9	3.5	1.3
2018	115.1	45.5	26.5	26.1	9.1	3.5	1.3
2019	116.3	45.9	26.7	26.5	9.2	3.6	1.3
2020	117.6	46.5	26.8	27.0	9.2	3.6	1.3
2021	118.8	47.1	26.8	27.6	9.2	3.6	1.3
2022	120.1	47.4	27.0	28.3	9.2	3.7	1.4
2023	121.3	47.9	26.9	29.0	9.2	3.7	1.4
2024	122.5	48.5	26.8	29.7	9.2	3.8	1.4
2025	123.8	49.1	26.7	30.4	9.2	3.9	1.4
2026	125.4	49.5	26.9	31.3	9.2	3.9	1.4
2027	126.7	50.3	26.7	31.9	9.2	4.0	1.4
2028	128.0	50.8	26.8	32.6	9.2	4.0	1.4
2029	129.3	51.4	26.7	33.3	9.2	4.1	1.4
2030	130.5	52.0	26.8	34.0	9.1	4.1	1.5
Average 2005-2007	**101.1**	**40.7**	**22.8**	**23.1**	**8.2**	**2.6**	**0.9**
Average 2010-2030	**118.0**	**46.6**	**26.3**	**28.0**	**8.9**	**3.6**	**1.3**
Average 2010-1019	**111.3**	**43.9**	**25.7**	**25.4**	**8.6**	**3.3**	**1.2**
Average 2020-1030	**124.0**	**49.1**	**26.8**	**30.5**	**9.2**	**3.9**	**1.4**

Data from 2005 are actual.

Table A.9. U.S. Energy Consumption by Fuel, Carbon-Based Tax Package, 2010-2030 (in quadrillion BTU)

Year	Total	Liquid	Natural Gas	Coal	Nuclear	Biofuels	Renewables
2010	104.6	41.1	24.5	22.2	8.3	4.2	1.2
2011	105.1	41.4	24.8	21.9	8.4	4.3	1.2
2012	105.9	41.8	25.1	21.6	8.4	4.6	1.3
2013	106.7	42.1	25.5	21.2	8.4	4.8	1.5
2014	107.5	42.6	25.5	20.9	8.5	5.2	1.6
2015	108.3	42.9	25.9	20.5	8.6	5.5	1.8
2016	109.3	43.3	25.9	20.3	8.7	5.9	2.0
2017	110.2	43.6	25.7	20.2	8.9	6.3	2.2
2018	111.1	44.0	25.7	19.8	9.0	6.8	2.5
2019	112.1	44.4	26.0	19.2	9.1	7.2	2.8
2020	113.2	44.8	26.2	19.0	9.2	7.8	2.9
2021	114.0	45.2	26.1	18.5	9.3	8.5	3.1
2022	114.9	45.5	26.2	18.1	9.4	9.2	3.2
2023	115.6	45.9	25.9	17.5	9.6	10.0	3.5
2024	116.3	46.3	25.9	16.6	9.7	10.8	3.6
2025	117.2	46.7	25.9	16.4	9.8	11.3	3.8
2026	118.1	47.2	25.8	16.0	9.8	11.7	4.1
2027	119.0	47.5	25.9	15.9	10.0	12.1	4.2
2028	119.8	47.9	26.0	15.6	10.1	12.3	4.4
2029	120.7	48.4	26.0	15.6	10.2	12.5	4.7
2030	121.4	48.8	26.3	15.6	10.1	12.5	4.7
Average 2010-2030	**112.9**	**44.8**	**25.8**	**18.7**	**9.2**	**8.3**	**2.9**
Average 2010-2019	**108.1**	**42.7**	**25.5**	**20.8**	**8.6**	**5.5**	**1.8**
Average 2020-2030	**117.3**	**46.7**	**26.0**	**16.8**	**9.7**	**10.8**	**3.8**

Table A.10. U.S. Energy Consumption, Percentage Difference by Fuel, Carbon-Based Tax Package Versus Business As Usual, 2010-2030 (%)

Year	Total	Liquid	Natural Gas	Coal	Nuclear	Biofuels	Renewables
2010	-1.5%	-1.6%	-0.2%	-8.6%	0.0%	37.2%	4.6%
2011	-2.1%	-2.1%	-0.1%	-11.0%	0.0%	39.8%	5.1%
2012	-2.5%	-2.4%	-0.4%	-13.0%	0.0%	49.0%	6.1%
2013	-2.7%	-2.7%	0.0%	-15.1%	0.0%	53.4%	22.8%
2014	-3.0%	-2.6%	-0.6%	-17.5%	1.0%	59.6%	28.0%
2015	-3.2%	-2.8%	-0.9%	-19.4%	1.1%	61.9%	43.1%
2016	-3.4%	-3.0%	-1.4%	-21.2%	0.8%	69.8%	57.6%
2017	-3.4%	-3.2%	-2.1%	-22.4%	-0.1%	81.4%	71.4%
2018	-3.5%	-3.1%	-2.9%	-24.0%	-1.3%	91.6%	88.9%
2019	-3.6%	-3.3%	-2.3%	-27.5%	-1.1%	103.5%	111.0%
2020	-3.8%	-3.8%	-2.2%	-29.6%	-0.3%	117.8%	116.0%
2021	-4.0%	-3.9%	-2.6%	-33.1%	0.9%	132.7%	134.2%
2022	-4.4%	-4.0%	-3.1%	-36.1%	2.3%	147.9%	135.0%
2023	-4.7%	-4.1%	-3.9%	-39.6%	3.6%	167.2%	152.1%
2024	-5.1%	-4.5%	-3.5%	-43.9%	4.9%	186.8%	156.6%
2025	-5.3%	-4.8%	-3.1%	-46.0%	5.7%	193.3%	170.1%
2026	-5.9%	-4.7%	-4.2%	-48.8%	6.6%	198.2%	191.2%
2027	-6.1%	-5.5%	-3.0%	-50.1%	7.9%	203.7%	194.3%
2028	-6.4%	-5.7%	-2.8%	-52.0%	9.1%	207.2%	205.8%
2029	-6.7%	-5.9%	-2.7%	-53.1%	10.2%	205.5%	220.9%
2030	-7.0%	-6.1%	-1.6%	-54.3%	11.4%	202.8%	220.0%
Average 2010-2030	**-4.3%**	**-3.9%**	**-2.1%**	**-33.3%**	**3.1%**	**129.9%**	**116.2%**
Average 2010-2019	**-2.9%**	**-2.7%**	**-1.1%**	**-18.1%**	**0.0%**	**65.9%**	**45.3%**
Average 2020-2030	**-5.4%**	**-4.9%**	**-3.0%**	**-44.8%**	**5.7%**	**179.7%**	**173.5%**

Table A.11. GDP and Its Components, under Business-As-Usual Scenario, 2005-2030 (in billions 2005 dollars)

Year	GDP	Consumption	Investment	Government	Exports	Imports
2005	12,457	8,840	2,104	2,208	1,349	2,047
2010	14,415	10,268	2,409	2,387	1,991	2,615
2011	14,852	10,586	2,507	2,412	2,143	2,761
2012	15,255	10,869	2,562	2,439	2,310	2,881
2013	15,663	11,148	2,618	2,468	2,487	3,001
2014	16,111	11,443	2,706	2,498	2,674	3,139
2015	16,570	11,751	2,796	2,528	2,866	3,284
2016	17,062	12,073	2,892	2,560	3,086	3,441
2017	17,600	12,429	3,004	2,594	3,325	3,623
2018	18,122	12,789	3,125	2,628	3,546	3,817
2019	18,669	13,153	3,257	2,662	3,783	4,013
2020	19,256	13,538	3,420	2,701	4,038	4,242
2021	19,831	13,928	3,567	2,732	4,308	4,478
2022	20,388	14,305	3,710	2,765	4,587	4,726
2023	20,959	14,688	3,870	2,796	4,880	4,993
2024	21,556	15,081	4,050	2,830	5,190	5,281
2025	22,173	15,479	4,253	2,866	5,518	5,592
2026	22,801	15,887	4,468	2,901	5,862	5,931
2027	23,430	16,303	4,676	2,938	6,223	6,289
2028	24,052	16,721	4,866	2,976	6,603	6,659
2029	24,697	17,144	5,092	3,016	6,999	7,061
2030	25,355	17,569	5,340	3,055	7,414	7,492
Averages 2005-2007	**12,837**	**9,101**	**2,179**	**2,250**	**1,468**	**2,158**
Averages 2010-2030	**19,467**	**13,674**	**3,580**	**2,702**	**4,278**	**4,539**
Averages 2010-2019	**16,432**	**11,651**	**2,788**	**2,518**	**2,821**	**3,257**
Averages 2020-2030	**22,227**	**15,513**	**4,301**	**2,870**	**5,602**	**5,704**

Data from 2005-2006 are actual.

Table A.12. GDP and Its Components, under Carbon-Based Tax Package, 2010-2030 (in billions 2005 dollars)

Year	GDP	Consumption	Investment	Government	Exports	Imports
2010	14,393	10,245	2,397	2,391	1,989	2,605
2011	14,775	10,520	2,473	2,415	2,135	2,737
2012	15,153	10,774	2,525	2,442	2,299	2,847
2013	15,572	11,052	2,595	2,473	2,475	2,971
2014	16,031	11,350	2,692	2,505	2,661	3,112
2015	16,496	11,661	2,785	2,537	2,851	3,258
2016	17,003	11,991	2,886	2,571	3,070	3,416
2017	17,550	12,355	2,998	2,607	3,309	3,600
2018	18,078	12,720	3,118	2,643	3,530	3,795
2019	18,625	13,083	3,247	2,678	3,767	3,990
2020	19,199	13,455	3,400	2,718	4,021	4,212
2021	19,756	13,827	3,539	2,749	4,287	4,439
2022	20,301	14,191	3,680	2,783	4,562	4,682
2023	20,863	14,564	3,838	2,816	4,851	4,945
2024	21,448	14,944	4,017	2,851	5,156	5,231
2025	22,052	15,328	4,218	2,887	5,478	5,538
2026	22,663	15,718	4,429	2,923	5,815	5,868
2027	23,269	16,114	4,630	2,961	6,168	6,220
2028	23,873	16,513	4,819	2,999	6,538	6,583
2029	24,499	16,918	5,042	3,040	6,926	6,981
2030	25,141	17,328	5,292	3,079	7,331	7,409
Averages 2010-2030	**19,369**	**13,555**	**3,553**	**2,718**	**4,248**	**4,497**
Averages 2010-2019	**16,368**	**11,575**	**2,772**	**2,526**	**2,809**	**3,233**
Averages 2020-2030	**22,097**	**15,355**	**4,264**	**2,892**	**5,557**	**5,646**

Table A.13. GDP and Its Components, Percentage Difference between Carbon-Based Tax Package and Business-As-Usual Scenarios, 2010-2030

Year	GDP	Consumption	Investment	Government	Exports	Imports
2010	-0.2%	-0.2%	-0.5%	0.2%	-0.1%	-0.4%
2011	-0.5%	-0.6%	-1.3%	0.1%	-0.4%	-0.9%
2012	-0.7%	-0.9%	-1.4%	0.1%	-0.5%	-1.1%
2013	-0.6%	-0.9%	-0.9%	0.2%	-0.5%	-1.0%
2014	-0.5%	-0.8%	-0.5%	0.3%	-0.5%	-0.9%
2015	-0.4%	-0.8%	-0.4%	0.4%	-0.5%	-0.8%
2016	-0.3%	-0.7%	-0.2%	0.4%	-0.5%	-0.7%
2017	-0.3%	-0.6%	-0.2%	0.5%	-0.5%	-0.6%
2018	-0.2%	-0.5%	-0.2%	0.6%	-0.5%	-0.6%
2019	-0.2%	-0.5%	-0.3%	0.6%	-0.4%	-0.6%
2020	-0.3%	-0.6%	-0.6%	0.6%	-0.4%	-0.7%
2021	-0.4%	-0.7%	-0.8%	0.7%	-0.5%	-0.9%
2022	-0.4%	-0.8%	-0.8%	0.7%	-0.6%	-0.9%
2023	-0.5%	-0.8%	-0.8%	0.7%	-0.6%	-1.0%
2024	-0.5%	-0.9%	-0.8%	0.7%	-0.7%	-1.0%
2025	-0.5%	-1.0%	-0.8%	0.7%	-0.7%	-1.0%
2026	-0.6%	-1.1%	-0.9%	0.8%	-0.8%	-1.1%
2027	-0.7%	-1.2%	-1.0%	0.8%	-0.9%	-1.1%
2028	-0.7%	-1.2%	-1.0%	0.8%	-1.0%	-1.1%
2029	-0.8%	-1.3%	-1.0%	0.8%	-1.1%	-1.1%
2030	-0.8%	-1.4%	-0.9%	0.8%	-1.1%	-1.1%
Averages 2010-2030	**-0.5%**	**-0.9%**	**-0.8%**	**0.6%**	**-0.7%**	**-0.9%**
Averages 2010-2019	**-0.4%**	**-0.7%**	**-0.6%**	**0.3%**	**-0.4%**	**-0.7%**
Averages 2020-2030	**-0.6%**	**-1.0%**	**-0.9%**	**0.7%**	**-0.8%**	**-1.0%**

Table A.14. Value of Shipments by Selected Sectors, Business-As-Usual Scenario, 2005-2030 (in billions 2005 dollars)

Year	All Industries	Non-Manufacturing	Manufacturing		
			All	Energy Intensive	Non-Energy Intensive
2005	6,497	1,734	4,763	1,308	3,455
2010	7,095	1,797	5,298	1,426	3,872
2011	7,260	1,816	5,444	1,446	3,998
2012	7,430	1,837	5,593	1,468	4,125
2013	7,588	1,861	5,727	1,485	4,242
2014	7,752	1,887	5,865	1,504	4,361
2015	7,930	1,918	6,012	1,522	4,489
2016	8,110	1,953	6,157	1,540	4,617
2017	8,264	1,983	6,281	1,554	4,727
2018	8,418	2,017	6,401	1,569	4,832
2019	8,580	2,046	6,534	1,589	4,944
2020	8,774	2,081	6,693	1,613	5,081
2021	8,956	2,107	6,849	1,635	5,213
2022	9,126	2,124	7,002	1,655	5,347
2023	9,286	2,138	7,148	1,674	5,474
2024	9,466	2,157	7,309	1,698	5,611
2025	9,675	2,185	7,490	1,721	5,769
2026	9,896	2,215	7,680	1,744	5,936
2027	10,106	2,235	7,871	1,770	6,101
2028	10,294	2,241	8,054	1,796	6,258
2029	10,489	2,257	8,233	1,818	6,414
2030	10,697	2,280	8,417	1,841	6,576
Average 2005-2007	**6,633**	**1,744**	**4,889**	**1,342**	**3,547**
Average 2010-2030	**8,819**	**2,054**	**6,765**	**1,622**	**5,142**
Average 2010-2019	**7,843**	**1,911**	**5,931**	**1,510**	**4,421**
Average 2020-2030	**9,706**	**2,184**	**7,522**	**1,724**	**5,798**

Data from 2005-2006 are actual.

Table A.15. Value of Shipment by Selected Sectors, Carbon-Based Tax Package, 2010-2030 (in billions 2005 dollars)

Year	All Industries	Non-Manufacturing	Manufacturing		
			All	Energy Intensive	Non-Energy Intensive
2010	7,058	1,791	5,267	1,416	3,851
2011	7,185	1,800	5,385	1,426	3,959
2012	7,340	1,814	5,526	1,444	4,082
2013	7,508	1,844	5,665	1,460	4,205
2014	7,676	1,873	5,803	1,477	4,326
2015	7,852	1,908	5,945	1,493	4,452
2016	8,038	1,946	6,092	1,510	4,582
2017	8,195	1,979	6,216	1,524	4,693
2018	8,350	2,014	6,336	1,538	4,797
2019	8,516	2,045	6,470	1,557	4,913
2020	8,691	2,077	6,614	1,577	5,037
2021	8,855	2,098	6,757	1,596	5,161
2022	9,020	2,111	6,909	1,614	5,295
2023	9,177	2,123	7,054	1,632	5,423
2024	9,349	2,142	7,207	1,651	5,556
2025	9,551	2,169	7,381	1,670	5,711
2026	9,754	2,196	7,558	1,690	5,868
2027	9,946	2,213	7,733	1,710	6,023
2028	10,122	2,217	7,905	1,731	6,174
2029	10,306	2,232	8,074	1,750	6,324
2030	10,509	2,254	8,255	1,771	6,484
Average 2010-2030	**8,714**	**2,040**	**6,674**	**1,583**	**5,091**
Average 2010-2019	**7,772**	**1,901**	**5,870**	**1,485**	**4,386**
Average 2020-2030	**9,571**	**2,167**	**7,404**	**1,672**	**5,732**

Table A.16. Value of Shipments by Selected Sectors, Percentage Difference between Carbon-Based Tax Package and Business-As-Usual, 2010-2030

Year	All Industries	Non-Manufacturing	Manufacturing		
			All	Energy Intensive	Non-Energy Intensive
2010	-0.5%	-0.3%	-0.6%	-0.7%	-0.5%
2011	-1.0%	-0.9%	-1.1%	-1.4%	-1.0%
2012	-1.2%	-1.3%	-1.2%	-1.6%	-1.1%
2013	-1.0%	-0.9%	-1.1%	-1.7%	-0.9%
2014	-1.0%	-0.7%	-1.1%	-1.8%	-0.8%
2015	-1.0%	-0.5%	-1.1%	-1.9%	-0.8%
2016	-0.9%	-0.4%	-1.1%	-2.0%	-0.8%
2017	-0.8%	-0.2%	-1.0%	-2.0%	-0.7%
2018	-0.8%	-0.1%	-1.0%	-2.0%	-0.7%
2019	-0.8%	-0.1%	-1.0%	-2.0%	-0.6%
2020	-0.9%	-0.2%	-1.2%	-2.2%	-0.8%
2021	-1.1%	-0.4%	-1.3%	-2.4%	-1.0%
2022	-1.2%	-0.6%	-1.3%	-2.5%	-1.0%
2023	-1.2%	-0.7%	-1.3%	-2.5%	-0.9%
2024	-1.2%	-0.7%	-1.4%	-2.7%	-1.0%
2025	-1.3%	-0.7%	-1.4%	-2.9%	-1.0%
2026	-1.4%	-0.9%	-1.6%	-3.1%	-1.1%
2027	-1.6%	-1.0%	-1.8%	-3.4%	-1.3%
2028	-1.7%	-1.1%	-1.8%	-3.6%	-1.3%
2029	-1.8%	-1.1%	-1.9%	-3.8%	-1.4%
2030	-1.8%	-1.1%	-1.9%	-3.8%	-1.4%
Average 2010-2030	**-1.2%**	**-0.7%**	**-1.3%**	**-2.4%**	**-1.0%**
Average 2010-2019	**-0.9%**	**-0.5%**	**-1.0%**	**-1.7%**	**-0.8%**
Average 2020-2030	**-1.4%**	**-0.8%**	**-1.6%**	**-3.0%**	**-1.1%**

Table A.17. Unemployment Rate and Total Employment by Selected Sectors, Business-As-Usual Scenario, 2005-2030 (% and millions of people)

Year	Unemployment Rate	Total Non-Farm Employment	Industrial Employment		
			Total	Non-Manufacturing	Manufacturing
2005	5.1%	133.4	25.2	10.9	14.2
2010	4.8%	141.9	25.0	11.2	13.8
2011	4.8%	143.2	25.1	11.3	13.8
2012	4.9%	144.3	25.1	11.4	13.8
2013	5.0%	145.1	25.2	11.5	13.7
2014	5.0%	146.0	25.3	11.6	13.7
2015	5.0%	147.0	25.5	11.8	13.7
2016	4.9%	148.1	25.7	12.0	13.7
2017	4.8%	149.6	25.8	12.2	13.6
2018	4.7%	151.1	25.9	12.4	13.6
2019	4.6%	152.8	26.0	12.5	13.5
2020	4.5%	154.6	26.1	12.7	13.4
2021	4.4%	156.4	26.1	12.8	13.3
2022	4.4%	158.0	26.1	12.9	13.2
2023	4.4%	159.5	26.1	12.9	13.2
2024	4.5%	160.9	26.1	13.0	13.1
2025	4.5%	162.3	26.1	13.2	13.0
2026	4.6%	163.7	26.1	13.3	12.9
2027	4.6%	165.2	26.1	13.4	12.8
2028	4.7%	166.6	26.0	13.3	12.7
2029	4.7%	167.9	26.0	13.4	12.6
2030	4.7%	169.2	26.0	13.5	12.5
Averages 2005-2007	**4.9%**	**135.2**	**25.3**	**11.1**	**14.2**
Averages 2010-2030	**4.7%**	**154.9**	**25.8**	**12.5**	**13.3**
Averages 2010-2019	**4.8%**	**146.9**	**25.5**	**11.8**	**13.7**
Averages 2020-2030	**4.5%**	**162.2**	**26.1**	**13.1**	**13.0**

Data from 2005-2006 are actual.

Table A.18. Unemployment Rate and Total Employment by Selected Sectors, Carbon-Based Tax Package, 2010-2030 (% and millions of people)

Year	Unemployment Rate	Total Non-Farm Employment	Industrial Employment		
			Total	Non-Manufacturing	Manufacturing
2010	4.9	141.8	25.0	11.2	13.8
2011	5.0	142.9	24.9	11.3	13.6
2012	5.1	143.7	24.9	11.3	13.6
2013	5.2	144.6	25.0	11.4	13.6
2014	5.2	145.6	25.1	11.6	13.5
2015	5.1	146.7	25.3	11.8	13.5
2016	5.0	147.9	25.5	12.0	13.5
2017	4.8	149.5	25.7	12.2	13.5
2018	4.7	151.2	25.8	12.4	13.4
2019	4.6	152.9	25.9	12.6	13.3
2020	4.5	154.7	26.0	12.8	13.2
2021	4.4	156.4	26.0	12.9	13.2
2022	4.4	157.9	26.0	12.9	13.1
2023	4.5	159.4	26.0	13.0	13.0
2024	4.6	160.8	26.0	13.1	12.9
2025	4.6	162.2	26.0	13.2	12.8
2026	4.7	163.5	26.0	13.3	12.7
2027	4.8	164.9	25.9	13.3	12.6
2028	4.8	166.2	25.8	13.3	12.5
2029	4.9	167.5	25.7	13.4	12.4
2030	4.9	168.8	25.7	13.4	12.3
Averages 2010-2030	**4.8**	**154.7**	**25.6**	**12.5**	**13.1**
Averages 2010-2019	**5.0**	**146.7**	**25.3**	**11.8**	**13.5**
Averages 2020-2030	**4.6**	**162.0**	**25.9**	**13.1**	**12.8**

Table A.19.

Unemployment Rate and Total Employment by Selected Sectors, Percentage Difference between Carbon-Based Tax Package and Business As Usual, 2010-2030

Year	Unemployment Rate	Total Non-Farm Employment	Industrial Employment		
			Total	Non-Manufacturing	Manufacturing
2010	0.1	0.0%	-0.2%	-0.1%	-0.3%
2011	0.2	-0.3%	-0.7%	-0.4%	-0.9%
2012	0.3	-0.4%	-1.0%	-0.8%	-1.1%
2013	0.3	-0.4%	-0.9%	-0.8%	-1.1%
2014	0.2	-0.3%	-0.8%	-0.5%	-1.0%
2015	0.2	-0.2%	-0.7%	-0.2%	-1.0%
2016	0.1	-0.1%	-0.5%	0.0%	-1.0%
2017	0.0	0.0%	-0.4%	0.3%	-1.0%
2018	0.0	0.0%	-0.3%	0.4%	-1.0%
2019	0.0	0.0%	-0.2%	0.5%	-0.9%
2020	0.0	0.0%	-0.3%	0.5%	-1.0%
2021	0.0	0.0%	-0.4%	0.4%	-1.2%
2022	0.1	0.0%	-0.5%	0.3%	-1.2%
2023	0.1	-0.1%	-0.5%	0.2%	-1.2%
2024	0.1	-0.1%	-0.6%	0.1%	-1.2%
2025	0.1	-0.1%	-0.6%	0.1%	-1.3%
2026	0.1	-0.1%	-0.7%	0.0%	-1.4%
2027	0.1	-0.2%	-0.8%	-0.1%	-1.6%
2028	0.2	-0.2%	-0.9%	-0.2%	-1.6%
2029	0.2	-0.2%	-1.0%	-0.2%	-1.7%
2030	0.2	-0.3%	-1.0%	-0.2%	-1.7%
Averages 2010-2030	**0.1**	**-0.1%**	**-0.6%**	**0.0%**	**-1.2%**
Averages 2010-2019	**0.1**	**-0.2%**	**-0.6%**	**-0.1%**	**-0.9%**
Averages 2020-2030	**0.1**	**-0.1%**	**-0.7%**	**0.1%**	**-1.4%**

Table A.20. Distribution of U.S. Energy Consumption by Broad Sector under Carbon-Based Tax Package, 2010-2030

Year	Residential	Commercial	Industrial	Transportation
2010	15.9%	11.7%	33.8%	38.7%
2011	15.9%	11.8%	33.5%	38.9%
2012	15.9%	11.9%	33.3%	39.0%
2013	15.8%	12.0%	33.1%	39.1%
2014	15.8%	12.0%	32.9%	39.3%
2015	15.7%	12.1%	32.8%	39.4%
2016	15.7%	12.1%	32.6%	39.5%
2017	15.6%	12.2%	32.5%	39.7%
2018	15.6%	12.2%	32.4%	39.8%
2019	15.5%	12.2%	32.4%	39.9%
2020	15.5%	12.3%	32.3%	39.9%
2021	15.4%	12.3%	32.3%	40.0%
2022	15.3%	12.4%	32.2%	40.1%
2023	15.2%	12.4%	32.1%	40.2%
2024	15.2%	12.5%	31.9%	40.3%
2025	15.1%	12.6%	31.9%	40.4%
2026	15.0%	12.6%	31.8%	40.6%
2027	15.0%	12.7%	31.7%	40.7%
2028	14.9%	12.7%	31.6%	40.8%
2029	14.8%	12.8%	31.5%	40.9%
2030	14.7%	12.8%	31.4%	41.0%
Averages 2010-2030	**15.4%**	**12.3%**	**32.4%**	**39.9%**
Averages 2010-2019	**15.7%**	**12.0%**	**32.9%**	**39.3%**
Averages 2020-2030	**15.1%**	**12.6%**	**31.9%**	**40.4%**

Table A.21. **Revenue Shift under the Carbon-Based Tax Package – Option 1: Revenues from Payroll and Carbon-Based Taxes, and Potential Payroll Tax Rate Relief, 2010-2030** (% and in billions of current dollars)

Year	OASDI Revenues	Carbon-Tax Revenues for Payroll Tax Relief	Payroll Tax Relief as Share of OASDI Revenues	New Payroll Tax Rate
2010	$783.9	$84.1	10.7%	11.1%
2011	788.7	97.1	12.3%	10.9%
2012	861.0	110.7	12.9%	10.8%
2013	902.3	124.5	13.8%	10.7%
2014	943.6	138.2	14.6%	10.6%
2015	985.2	152.5	15.5%	10.5%
2016	1,033.3	167.6	16.2%	10.4%
2017	1,085.0	182.9	16.9%	10.3%
2018	1,137.2	198.5	17.5%	10.2%
2019	1,193.3	214.1	17.9%	10.2%
2020	1,250.3	231.5	18.5%	10.1%
2021	1,311.6	247.7	18.9%	10.1%
2022	1,376.0	265.0	19.3%	10.0%
2023	1,442.1	281.7	19.5%	10.0%
2024	1,513.1	298.0	19.7%	10.0%
2025	1,584.7	316.9	20.0%	9.9%
2026	1,661.7	335.0	20.2%	9.9%
2027	1,741.6	354.7	20.4%	9.9%
2028	1,824.0	373.6	20.5%	9.9%
2029	1,909.1	392.9	20.6%	9.8%
2030	1,994.2	413.1	20.7%	9.8%
Averages 2010-2030	**$1,301.0**	**237.2**	**17.5%**	**10.2%**
Averages 2010-2019	**$971.3**	**147.0**	**14.8%**	**10.6%**
Averages 2020-2030	**$1,600.8**	**319.1**	**19.8%**	**9.9%**

Table A.22.

Revenue Shift under the Carbon-Based Tax Package – Option 2: Carbon-Based Tax Revenues for Payroll Tax Relief, Potential Initial Exemption from Payroll Taxes and Equivalent Payments per Working Person, 2010-2030 (in current dollars)

Year	Employment (millions)	Total Payroll Tax Relief ($ billions)	Initial Exemption from Payroll Tax	Equivalent Direct Payment per Working Person
2010	141.8	$84.1	$5,359	$593
2011	142.9	$97.1	$6,253	$680
2012	143.7	$110.7	$7,132	$771
2013	144.6	$124.5	$8,056	$861
2014	145.6	$138.2	$8,969	$949
2015	146.7	$152.5	$9,922	$1,040
2016	147.9	$167.6	$10,902	$1,133
2017	149.5	$182.9	$11,863	$1,223
2018	151.2	$198.5	$12,826	$1,313
2019	152.9	$214.1	$13,761	$1,400
2020	154.7	$231.5	$14,810	$1,496
2021	156.4	$247.7	$15,747	$1,584
2022	157.9	$265.0	$16,763	$1,678
2023	159.4	$281.7	$17,712	$1,767
2024	160.8	$298.0	$18,605	$1,853
2025	162.2	$316.9	$19,699	$1,954
2026	163.5	$335.0	$20,694	$2,049
2027	164.9	$354.7	$21,777	$2,150
2028	166.2	$373.6	$22,793	$2,247
2029	167.5	$392.9	$23,821	$2,346
2030	168.8	$413.1	$24,900	$2,448
Averages 2010-2030	**154.7**	**$237.2**	**$14,874**	**$1,501**
Averages 2010-2019	**146.7**	**$147.0**	**$9,504**	**$996**
Averages 2020-2030	**162.0**	**$319.1**	**$19,756**	**$1,961**

Table A.23. **Revenue Shift under the Carbon-Based Tax Package – Option 3: Carbon-Based Tax Revenues for Tax Relief and Payments per U.S. Household, 2010-2030** (in current dollars)

Year	Households (millions)	Tax Relief from Carbon-Based Tax ($ billions)	Payments per Household
2010	120.7	$84.1	$697
2011	121.8	$97.1	798
2012	122.8	$110.7	902
2013	123.9	$124.5	1,005
2014	124.9	$138.2	1,106
2015	126.0	$152.5	1,211
2016	127.0	$167.6	1,319
2017	128.0	$182.9	1,428
2018	129.1	$198.5	1,537
2019	130.1	$214.1	1,645
2020	131.2	$231.5	1,765
2021	132.2	$247.7	1,873
2022	133.3	$265.0	1,989
2023	134.3	$281.7	2,097
2024	135.4	$298.0	2,200
2025	136.5	$316.9	2,322
2026	137.6	$335.0	2,435
2027	138.7	$354.7	2,558
2028	139.8	$373.6	2,673
2029	140.9	$392.9	2,789
2030	142.0	$413.1	2,909
Averages 2010-2030	**131.2**	**$237.2**	**$1,774.2**
Averages 2010-2019	**125.4**	**$147.0**	**$1,164.8**
Averages 2010-2030	**136.5**	**$319.1**	**$2,328.2**

Table A.24.

World Carbon Dioxide Emissions by Region and Major Countries, under Business-As-Usual Scenario, 2004-2030
(in millions of metric tons of CO_2 equivalent)[47]

Year	2004	2010	2015	2030	Change, 2004-2030
World	**26,922**	**30,860**	**33,889**	**42,880**	**1.8**
OECD	**13,457**	**14,105**	**14,692**	**16,654**	**0.8**
North America	**6,893**	**7,343**	**7,780**	**9,400**	**1.2**
United States	5,923	6,214	6,589	7,950	1.1
Canada	584	648	659	750	1.0
Mexico	385	481	532	699	2.3
Europe	**4,381**	**4,493**	**4,558**	**4,684**	**0.3**
Asia	**2,183**	**2,269**	**2,353**	**2,569**	**0.6**
Japan	1,262	1,274	1,290	1,306	0.1
South Korea	497	523	574	691	1.3
Australia/New Zealand	424	472	490	573	1.2
Non-OECD	**13,465**	**16,755**	**19,197**	**26,226**	**2.6**
Europe and Eurasia	**2,819**	**3,067**	**3,301**	**3,878**	**1.2**
Russia	1,685	1,809	1,908	2,185	1.0
Other	1,134	1,258	1,393	1,693	1.6
Asia	**7,411**	**9,711**	**11,404**	**16,536**	**3.1**
China	4,707	6,497	7,607	11,239	3.4
India	1,111	1,283	1,507	2,156	2.6
Other	1,593	1,930	2,289	3,141	2.6
Middle East	**1,289**	**1,602**	**1,788**	**2,306**	**2.3**
Africa	**919**	**1,140**	**1,291**	**1,655**	**2.3**
Central/South America	**1,027**	**1,235**	**1,413**	**1,851**	**2.3**
Brazil	334	403	454	597	2.3
Other	693	831	959	1,254	2.3

47 EIA, International Energy Outlook 2007; http://www.eia.doe.gov/oiaf/ieo/ieorefcase.html.

Table A.25. **World Energy Consumption by Fuel, under Business-As-Usual Scenario, 1990-2030,** (in quadrillion BTU)[48]

Year	1990	2004	2015	2030	Average Annual Percent Change, 2004-2030
World	**347.3**	**446.7**	**559.4**	**701.6**	**1.8%**
Liquids	136.2	168.2	197.6	238.9	1.4%
Natural Gas	75.2	103.4	134.3	170.4	1.9%
Coal	89.4	114.5	151.6	199.1	2.2%
Nuclear	20.4	27.5	32.5	39.7	1.4%
Other	26.2	33.2	43.4	53.5	1.9%
OECD	**197.4**	**239.8**	**265.2**	**298.0**	**0.8%**
Liquids	83.4	98.9	103.5	114.4	0.6%
Natural Gas	37.2	53.1	64.0	72.3	1.2%
Coal	43.5	46.6	50.7	59.3	0.9%
Nuclear	17.3	23.2	25.3	27.3	0.6%
Other	15.9	17.9	21.8	24.7	1.2%
Non-OECD	**150.0**	**206.9**	**294.2**	**403.5**	**2.6%**
Liquids	52.7	69.3	94.1	124.4	2.3%
Natural Gas	38.0	50.3	70.4	98.1	2.6%
Coal	45.9	67.9	100.9	139.8	2.8%
Nuclear	3.1	4.3	7.2	12.4	4.2%
Other	10.3	15.3	21.6	28.8	2.5%

48 EIA, International Energy Outlook 2007; http://www.eia.doe.gov/oiaf/ieo/ieorefcase.html.

About the Authors

Robert J. Shapiro is the chairman of Sonecon, LLC, a private firm that advises U.S. and foreign businesses, governments and nonprofit organizations on market conditions and economic policy. Dr. Shapiro has advised, among others, U.S. President Bill Clinton, British Prime Minister Tony Blair, and Senators Barack Obama, Hillary Clinton and Evan Bayh; private firms including Amgen, AT&T, Gilead Sciences, Google, MCI, Inc., SLM Corporation, Nordstjernan of Sweden, and Fujitsu of Japan; and nonprofit organizations including the American Public Transportation Association, the Education Finance Council and the U.S. Chamber of Commerce. He is also a Senior Fellow of the Georgetown University School of Business, a fellow of Progressive Policy Institute (PPI), Director of the NDN Center on Globalization, chair of the U.S. Climate Task Force, co-chair of America Task Force Argentina, and a Director of the Ax:son-Johnson Foundation in Sweden. From 1997 to 2001, he was Under Secretary of Commerce for Economic Affairs. Prior to that, he was co-founder and Vice President of PPI. Dr. Shapiro also served as the Principal Economic Advisor to Bill Clinton in his 1991-1992 presidential campaign, Senior Economic Advisor to Albert Gore, Jr. in 2000 and John Kerry in 2004, Legislative Director for Senator Daniel P. Moynihan, and Associate Editor of *U.S. News & World Report.* He has been a Fellow of Harvard University, the Brookings Institution and the National Bureau of Economic Research. He holds a Ph.D. and M.A. degree from Harvard University, a M.Sc. from the London School of Economics, and an A.B. degree from the University of Chicago. He is widely published in scholarly and popular journals, and the author most recently of *Futurecast: How Superpowers, Populations and Globalization Will Change the Way You Live and Work* (St. Martin's Press, April 2008), named by the National Chamber Foundation as one of the 10 most important books for policymakers in 2008.

Nam D. Pham is the founder and President of NDP Group, LLC, an economics consulting firm that specializes in assessing complex issues in finance, international trade and economic development. Clients of NDP Group include U.S. and foreign corporations, financial institutions, federal and local governments, trade associations and multinational organizations. Prior to founding NDP Group in 2000, Dr. Pham was Vice President at Scudder Kemper Investments in Boston, where he was responsible for research, asset allocations and currency hedges for global and international bond funds. Before that, he was Chief Economist of the Asia Region for Standard & Poor's DRI in Boston. Dr. Pham also has extensive experience in multinational organizations and government agencies, including service as an economist at the World Bank and consultant to the Department of Commerce and the Federal Trade Commission. Dr. Pham also has been an adjunct professor at The George Washington University, where he has taught monetary economics, international trade and finance, macroeconomics and microeconomics. Dr. Pham earned a Ph.D. in economics from The George Washington University with concentrations in international trade and finance, economic development and applied microeconomics, an M.A. degree from Georgetown University, and a B.A. degree from the University of Maryland.

Arun S. Malik is an Associate Professor of Economics and Public Policy at The George Washington University. He received his Ph.D. from Johns Hopkins University and obtained a B.A. degree from Bowdoin College. Dr. Malik's research has focused on environmental policy design, the economics of crime and punishment, and, more recently, the economics of forest fire risk. In addition to his academic research and teaching, Dr. Malik has served as a consultant to a variety of organizations on topics ranging from climate change to environmental policy reform in transition economies.

The U.S. Climate Task Force

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