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ECONOMIC OUTCOMES OF A U.S. CARBON TAX

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Table of Acronyms

AEO: Annual Energy Outlook

BEV: Battery Electric Vehicle

BTL: Biomass to Liquids

CBO: Congressional Budget Office

CCS: Carbon Capture and Storage

CES: Constant Elasticity of Substitution

CGE: Computable General Equilibrium

C**NG**: Compressed Natural Gas

CO_2: Carbon Dioxide

DSM: Demand-Side Management

EIA: Energy Information Administration

EPA: U.S. Environmental Protection Agency

EV: Electrified Vehicle

FICA: Federal Insurance Contributions Act

GDP: Gross Domestic Product

GRP: Gross Regional Product

GSP: Gross State Product

GW: Gigawatt

HI: Hospital Insurance

kW: Kilowatt

kWh: Kilowatt-hour

LDV: Light Duty Vehicle

MM: Million

NBER: National Bureau of Economic Research

OECD: Organisation for Economic Co-operation and Development

PHEV: Plug-In Hybrid Electric Vehicle

PIT: Personal Income Tax

REC: Renewable Energy Credit

RPS: Renewable Portfolio Standard

TWh: Terawatt-hour

VMT: Vehicle Miles Traveled

EXECUTIVE SUMMARY

This report evaluates the potential impacts on the U.S. economy from possible future carbon taxes whose revenues would be devoted to a combination of debt and tax rate reduction. The results take into account the varied economic effects of fossil fuel cost increases due to a carbon tax as well as the positive economic effects of the assumption that carbon tax revenues would be used to reduce government debt and Federal taxes.

Objectives and Methodology

We use an economy-wide, computable general equilibrium (CGE) model (NERA's N_{ew}ERA model) to develop estimates of the effects of a carbon tax on the U.S. economic system, including:

1. **U.S. economy.** These effects include economic activity as measured by gross domestic product (GDP), personal income, and various measures of effects on workers. Results are developed for the United States as a whole and for individual sectors and regions (*e.g.*, gross regional product or GRP).
2. **Emissions and energy markets.** These effects include carbon dioxide (CO_2) emissions at the national, regional, and sectoral levels, and outcomes in energy markets, including electricity, natural gas, coal, and oil. We report national and regional results.

Such economic impact results are important so that the economic effects of a specific carbon tax policy can be compared to estimates of the environmental effects of the policy.

The N_{ew}ERA model combines a detailed plant-specific representation of the electricity sector and the related coal sector with representation of the rest of the sectors of the economy. Consumer choices and financial outcomes are also integral to the model projections. This model was designed to assess, on an integrated basis, the effects of major policies on electricity markets, other energy markets, and the overall economy. The model also projects reductions in CO_2 emissions that occur within U.S. borders.[1] N_{ew}ERA performs its analysis with varying regional detail. In this report, we provide results for the United States as a whole and for 11 regions of the U.S. Appendix A provides a detailed description of the N_{ew}ERA model.

Carbon Tax Cases Evaluated

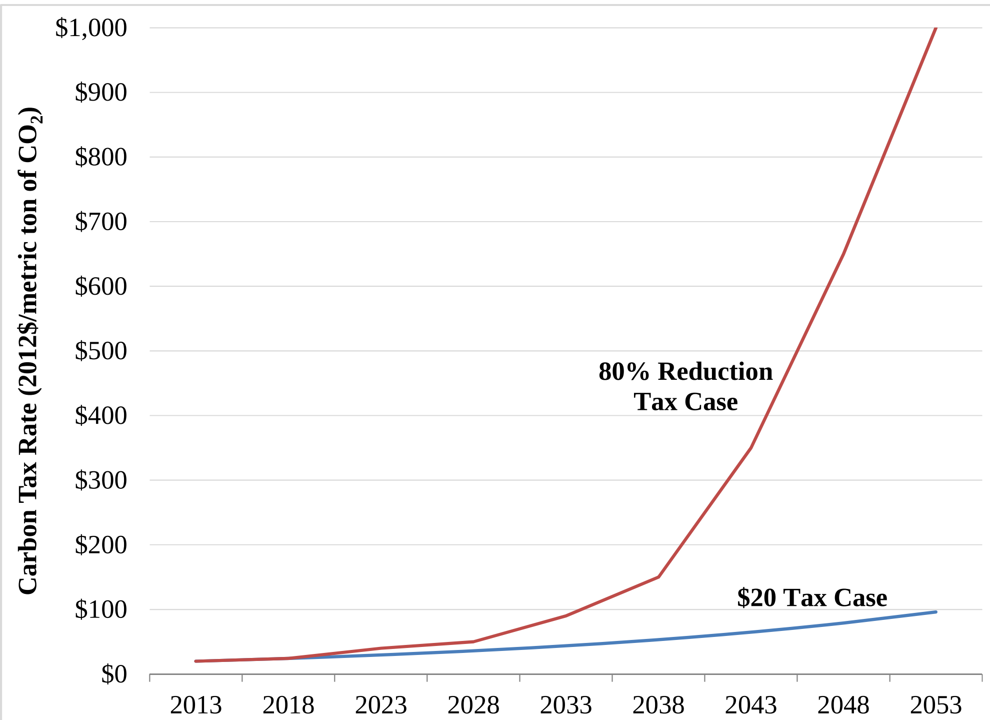
We have developed analyses for a "Baseline" case and two carbon tax cases that are added to the Baseline case's assumptions. All the results that describe changes in economic outcomes due to one of the carbon tax cases are changes relative to the value of that same economic variable in the Baseline case. The specific assumptions of the two carbon tax cases are as follows:

[1] This model does not, however, estimate the potential for the policy to cause increases in emissions outside of U.S. borders, a phenomenon known as "leakage."

1. **\$20 Tax Case:** This case assumes a carbon tax that begins at \$20/metric ton of CO_2 (2012 dollars) in 2013 and increases at 4% per year in real (2012) dollars.
2. **80% Reduction Tax Case:** This case is the same as the \$20 Tax Case up to 2018, at which time it is assumed to be set on a trajectory designed to target progress towards an 80% reduction in CO_2 emissions from 2005 levels by 2053, but with a maximum tax rate set at \$1,000/metric ton.

Both cases presume that the carbon tax would be levied "upstream" on primary fuels in order to cover the vast majority of U.S. carbon emissions. In both cases, the net Federal revenues from the carbon tax are used to reduce the Federal debt and to reduce marginal personal income tax (PIT) rates from their assumed levels in the Baseline. Figure 1 shows the assumed carbon tax rates for the two cases.

Figure 1: Carbon Tax Rates (2012\$/metric ton of CO_2) in the Two Carbon Tax Cases



The \$20 Tax Case is similar to policies suggested recently in reports by the Congressional Research Service and by a group at the Brookings Institution, although they differ in the specific uses of the carbon tax revenues.[2] Similar carbon tax levels to the \$20 Tax Case also have been

[2] J.L. Ramseur, J.A. Leggett and M.F. Sherlock, *Carbon Tax: Deficit Reduction and Other Considerations*, Congressional Research Service report for Congress #7-5700, September 17, 2012; M. Muro and J. Rothwell, "Cut to Invest: Institute a Modest Carbon Tax to Reduce Carbon Emissions, Finance Clean Energy Technology Development, Cut Taxes, and Reduce the Deficit." *Remaking Federalism/Renewing the Economy #7*, Brookings, November 13, 2012.

modeled by other researchers, but again with differing assumptions about how the carbon tax revenues would be recycled.[3]

The 80% Reduction Tax Case is motivated by a recognition that the $20 Tax Case is not projected to produce sufficient carbon emissions reductions to meet the commitments that have been discussed in international negotiations and embedded in prior Congressional legislative proposals for national cap-and-trade programs.[4] This second case represents a scenario in which a carbon tax policy begins with the same rates as the $20 Tax Case but then changes to substantially higher rates in order to target larger emissions reductions by the end of the period.

Baseline debt is also an important assumption in an analysis such as this. The baseline debt is projected initially based on tax rates in place during 2012, combined with current projected expenditure programs; however, the Baseline case also assumes that the debt will not exceed 100% of GDP. In the first modeled year in which the debt would otherwise exceed 100% of GDP (which is 2023 in this study), the 2012 tax rates are replaced by higher tax rates, set at pre-2001 levels. In addition to those tax rate increases, decreases in current projected entitlement spending are also implemented in the Baseline case to maintain a debt/GDP ratio of about 1.0. As discussed in more detail in the main body of this report, a lower national debt-to-GDP ratio is assumed to benefit the economy by lowering interest rates for Federal debt, leading to lower Federal interest payments, which lead to other positive economic impacts. Reductions in PIT rates relative to the Baseline also lead to positive economic impacts because the reductions in tax rates increase incentives to work and invest and also reduce the size of the "tax-interaction effect" associated with the overall cost of the carbon tax.

Effects on the U.S. Economy and U.S. Households

Figure 2 shows the net effects of the two carbon tax cases on the U.S. economy as measured by GDP and U.S. household consumption. (All dollar values in this report are in 2012 dollars.) Under the $20 Tax Case, GDP would be reduced from the Baseline levels by about 0.4% ($60 billion) in 2013 and by about 0.6% ($230 billion) in 2053. The negative impacts of the 80% Reduction Tax Case on GDP are substantially greater in the later time periods, reaching 3.6% (almost $1.4 trillion) by 2053.

[3] S. Rausch and J. Reilly, *Carbon Tax Revenue and the Budget Deficit: A Win-Win-Win Solution?* MIT Joint Program on the Science and Policy of Global Change, Report # 228, August 2012; W. McKibbin, A. Morris, P. Wilcoxen, and Y. Cai, *The Potential Role of a Carbon Tax in U.S. Fiscal Reform*, Climate and Energy Economics Discussion Paper, Brookings, July 24, 2012.

[4] For example, the Waxman-Markey Bill (H.R. 2454) passed by the U.S. House of Representatives in June 2009, would have required greenhouse gas emission reductions of 83% relative to 2005. It should be noted, however, that the Waxman-Markey Bill and other similar legislative proposals allowed for international offsets and had provisions for the banking of allowances.

Figure 2: Macroeconomic Impacts of Carbon Tax Cases

	Present Value	2013	2023	2033	2043	2053
Baseline						
GDP (Billions of 2012$)	$396,400	$14,940	$19,400	$24,680	$31,280	$38,120
$20 Tax Case						
GDP (% Change from Baseline)	-0.5%	-0.4%	-0.5%	-0.5%	-0.5%	-0.6%
Change in Avg. Consumption per Household[5]	-$310	-$20	-$340	-$350	-$440	-$440
80% Reduction Tax Case						
GDP (% Change from Baseline)	-1.2%	-0.4%	-0.5%	-1.0%	-2.5%	-3.6%
Change in Avg. Consumption per Household	-$920	-$80	-$690	-$860	-$1,510	-$2,680

Present value calculated using a 5% real discount rate, which is the rate used in the model.

Under the $20 Tax Case, average household consumption would be reduced by about $340 in 2033 and by about $440 in 2053, with an average present value reduction over the period from 2013 to 2053 of $310 per household. Under the 80% Reduction Tax Case, the average household consumption declines by about $860 in 2033 and by almost $2,700 in 2053, with an average present value reduction of $920 over the entire period.

These results indicate that the net aggregate effects of the two carbon tax cases on the U.S. economy and on U.S. household consumption would be negative. In other words, when considered at an aggregate level, the negative economic effects of both carbon tax cases outweigh their positive economic effects, which include estimates of the gains from using net carbon tax revenues to reduce both the Federal debt and Federal PIT rates. Our analysis of the economy-wide impacts of the policy indicates that although the net carbon tax revenues are positive in all years, their fiscal benefits to the economy are not large enough to outweigh the direct costs that the carbon tax imposes on the economy. We also find that the higher carbon tax case results in larger net negative aggregate impacts.

Figure 3 focuses on several dimensions of projected impacts on income from labor ("worker income") as a result of the carbon tax. The carbon tax leads to lower real wage rates because companies have higher costs and lower labor productivity under a carbon tax, effects that are partially offset by the lower Federal PIT rates that are allowed by the use of carbon tax revenues. Lower real wage rates directly reduce labor income per hour and thus lower workers' incomes even if they continue to work the same number of hours. However, the lower wage rate also decreases the willingness of workers to supply as many hours to the job market. That is, there is

[5] These changes in consumption are relative to an average Baseline household consumption of $94,000. Note that average household consumption is significantly larger than the more commonly-reported figure of median household consumption because of the impact of very high-income households. Also, average household consumption in the U.S. presently exceeds average household income, due to household debt.

an incremental shift towards greater demand for leisure, which implies reduced labor force participation. With fewer hours worked, total labor income declines by a greater percentage than does the wage rate. These are the net effects on labor in the aggregate, and include the positive benefits of increased labor demand in sectors providing energy and other goods and services that have low carbon-intensity.[6]

Figure 3: Labor Impacts of Carbon Tax Cases

	2013	**2023**	**2033**	**2043**	**2053**
Baseline Job-Equivalents (Thousands)*	138,700	153,100	168,100	183,600	201,000
$20 Tax Case					
Wage Rate (% Change from Baseline)	-0.8%	-1.0%	-0.9%	-1.1%	-1.2%
Labor Income (% Change from Baseline)	-1.0%	-1.1%	-1.1%	-1.2%	-1.4%
Job-Equivalents* (Change from Baseline, Thousands)	-1,510	-2,290	-2,520	-3,210	-3,770
80% Reduction Tax Case					
Wage Rate (% Change from Baseline)	-0.6%	-1.2%	-1.7%	-4.3%	-7.2%
Labor Income (% Change from Baseline)	-0.8%	-1.3%	-1.9%	-5.1%	-8.3%
Job-Equivalents* (Change from Baseline, Thousands)	-1,260	-2,750	-4,370	-11,860	-20,670

* Total job-equivalents equals total labor income change divided by the average annual income per job. This does not represent a projection of numbers of workers that may need to change jobs and/or be unemployed, as some or all of it could be spread across workers who remain employed.

The total reduction in labor income is spread over many workers, most of whom continue to work, but its dollar magnitude can be placed in context by estimating the equivalent number of average jobs that such labor payments would fund under baseline wage rates. To state the labor income changes in terms of such "job-equivalents" in Figure 3, the reduction in labor income is divided by the annual baseline income from the average job. Again, a loss of one job-equivalent does not necessarily mean one fewer employed person—it may be manifested as a combination of fewer people working and less income per worker. However, this measure allows us to express employment-related impacts in terms of an equivalent number of employees earning the average prevailing wage. Note that the N_{ew}ERA model, like many other similar economic models, does not develop projections of unemployment rates or layoffs associated with reductions in labor income; modeling such largely transitional phenomena would require a different type of modeling methodology.

[6] The Figure 3 shows that the two tax cases have different impacts labor impacts prior to 2023 even though the carbon prices are the same in those years because the model has perfect foresight. Therefore, decisions made in 2013 and 2018 are made with the full awareness that carbon prices are going to be significantly higher in the 80% Reduction Tax Case than in the $20 Tax Case starting in 2023, and this drives different optimal economic decisions in 2013 and 2018.

For the $20 Tax Case, labor income declines by about 1.0% to 1.4% throughout the period, resulting in job-equivalent losses that range from about 1.5 million job-equivalents in 2013 to about 3.8 million job-equivalents in 2053. Under the 80% Reduction Tax Case, labor income reductions range from about 1% in the early years to more than 8% by the end of the period, resulting in job-equivalent losses ranging from about 1.3 million job-equivalents in 2013 to almost 21 million job-equivalents by 2053.

Effects on Carbon Dioxide Emissions and Energy Markets

Figure 4 summarizes the effects of the two carbon tax cases on CO_2 emissions. For the $20 Tax Case, CO_2 emissions are projected to be reduced by almost 1,800 million metric tons by 2053; this reduction represents about a 30% reduction relative to the baseline level for 2053 and a 31% reduction relative to the 2005 level (5,988 million metric tons). The 80% Reduction Tax Case would, by design, result in substantially greater emission reductions. By 2053, the carbon tax would reduce CO_2 emissions by about 70% relative to the Baseline and about 71% relative to the 2005 level.[7]

Figure 4: CO_2 Emissions and Reductions of Carbon Tax Cases (Million Metric Tons of CO_2)

	2013	2023	2033	2043	2053
Baseline					
CO_2 Emissions	5,450	5,530	5,650	5,790	5,890
$20 Tax					
CO_2 Emissions	5,210	4,670	4,590	4,640	4,110
% Reduction from Baseline	*4%*	*16%*	*19%*	*20%*	*30%*
% Reduction from 2005	*13%*	*22%*	*23%*	*23%*	*31%*
80% Reduction					
CO_2 Emissions	5,210	4,400	3,610	2,590	1,760
% Reduction from Baseline	*4%*	*20%*	*36%*	*55%*	*70%*
% Reduction from 2005	*13%*	*27%*	*40%*	*57%*	*71%*

Figure 5 shows energy price projections under the Baseline and the two carbon tax cases (inclusive of the carbon tax on fossil fuels). The price changes relative to the Baseline case's levels reflect two effects: (1) the effect of the carbon tax on fossil fuels, which increases fossil fuel prices by an amount determined by the carbon content of the fuel and the level of the carbon price; and (2) the effect of market adjustments, as fossil fuel users substitute away from the higher-priced fuels (particularly a shift away from coal towards natural gas in the near term). Residential delivered electricity prices increase as a result of the increased costs for fossil fuels due to the carbon tax.

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[7] Although this case represents a sequence of carbon tax rates selected to place the U.S. economy on a path towards 80% reduction by 2053, capping the carbon tax rate at $1,000/ton (2012$) causes it to fall short of the 80% reduction mark in the last few years of the modeled time period.

Figure 5: Energy Prices of Carbon Tax Cases, Prices Including Carbon Tax (2012$)

	2013	2023	2033	2043	2053
Baseline Prices ($/MMBtu for Coal/Natural Gas, $/gallon for Gasoline, ¢/kWh for Electricity)					
Minemouth Coal	$1.61	$1.79	$2.01	$2.06	$1.76
Wellhead Natural Gas	$3.78	$4.85	$6.09	$8.42	$10.49
Gasoline	$3.51	$4.07	$4.31	$5.02	$5.51
Electricity (Residential)	12.0¢	13.7¢	14.3¢	16.0¢	17.1¢
$20 Tax Case ($/MMBtu for Coal/Natural Gas, $/gallon for Gasoline, ¢/kWh for Electricity)					
Minemouth Coal	$3.39	$4.34	$5.84	$7.84	$10.61
Wellhead Natural Gas	$5.43	$6.43	$8.46	$11.69	$15.14
Gasoline	$3.72	$4.37	$4.74	$5.64	$6.43
Electricity (Residential)	13.4¢	15.4¢	16.7¢	19.3¢	20.5¢
80% Reduction Tax Case ($/MMBtu for Coal/Natural Gas, $/gallon for Gasoline, ¢/kWh for Electricity)					
Minemouth Coal	$3.34	$5.35	$9.84	$34.47	$95.38
Wellhead Natural Gas	$5.42	$7.21	$11.28	$25.77	$62.66
Gasoline	$3.74	$4.43	$5.06	$8.03	$14.57
Electricity (Residential)	13.5¢	16.2¢	18.6¢	25.9¢	24.3¢

Figure 6 shows the effects of the two carbon tax cases on the commodity prices that natural gas and coal producers receive, *i.e.*, excluding the carbon tax. These trends are different for natural gas and coal. Coal prices received by producers decrease in all years in both cases, reflecting the shift away from coal due to the carbon tax. Natural gas prices received by producers increase in the early years (reflecting their lower carbon content relative to coal) but then decrease in the middle years (reflecting the eventual switch away from natural gas to low or zero-emitting fuels). Baseline prices are unchanged (and thus not displayed in Figure 6) since there is no carbon tax in the Baseline.

Figure 6: Energy Commodity Price Effects, Prices Excluding Carbon Tax

	2013	2023	2033	2043	2053
$20 Tax Case (Percentage Changes from Baseline)					
Minemouth Coal	-6.4%	-13%	-14%	-15%	-9.4%
Wellhead Natural Gas	16%	0.3%	0.7%	-2.0%	-4.3%
80% Reduction Tax Case (Percentage Changes from Baseline)					
Minemouth Coal	-9.0%	-11%	-31%	-22%	-15%
Wellhead Natural Gas	16%	4.8%	6.8%	-15%	-8.6%

Figure 7 shows projected impacts on the electricity sector in terms of coal electricity unit retirements and overall electricity demand. As expected, the imposition of a carbon tax increases the quantity of coal unit retirements, with higher tax rates leading to a greater level of retirements. Even the $20 Tax Case is projected to cause three times the amount of coal retirements by 2023 compared to the Baseline. The near-term retirements of the coal units are motivated by the anticipated higher carbon taxes in later years (which make further near-term capital investments to keep such plants operational uneconomical). The extent of the coal unit retirements is exacerbated by relatively low forecasted prices for natural gas. Under the $20 Tax Case, electricity demand declines about 11% below the Baseline level in 2033 and about 12% in 2053; the 80% Reduction Tax Case causes electricity demand to drop by about 17% in 2033 and more than 25% afterward relative to the Baseline.

Figure 7: Electricity Sector Impacts of Carbon Tax Cases

	2013	2023	2033	2043	2053
Baseline					
Coal Retirements (GW)	4	36	37	39	39
U.S. Electricity Demand (TWh)	3,990	4,280	4,640	4,990	5,380
$20 Tax Case					
Coal Retirements (GW)	5	108	112	119	160
U.S. Electricity Demand (TWh)	3,890	3,960	4,150	4,370	4,740
% Change (Relative to Baseline)	*-2.4%*	*-7.7%*	*-11%*	*-12%*	*-12%*
80% Reduction Tax Case					
Coal Retirements (GW)	5	141	213	295	295
U.S. Electricity Demand (TWh)	3,890	3,830	3,840	3,590	4,020
% Change (Relative to Baseline)	*-2.4%*	*-11%*	*-17%*	*-28%*	*-25%*

Conclusions

Our analysis has modeled the economic and energy market impacts of two carbon tax cases, one in which the carbon tax is set at $20 per metric ton of CO_2 in 2013 and increases by 4% per year in real (2012) dollars and one in which the carbon tax rate is the same in the early years but eventually increases to very high levels in efforts to target an 80% reduction in emissions by 2053. Under both cases, the net carbon tax revenues to the Federal government are used to reduce the Federal debt and PIT rates. We use a CGE model of the U.S. economy with regional and sectoral detail to estimate the economic effects of these carbon tax cases.

The model we use includes a methodology for estimating the national economic benefits from using part of the net carbon tax revenues to reduce Federal debt payments and part of the net carbon tax revenues to reduce the marginal tax rates on labor and capital. The combined economic gains from these two uses of net carbon tax revenues—reduced debt and reduced PIT rates—are estimated to be substantial under both carbon tax cases. Nevertheless, our analysis finds that those economic benefits are more than offset by the economic costs that result from the new tax burden of the carbon tax cases. Thus, our results indicate that the net economic impacts of both carbon tax cases are negative, as judged by the summary impact measures for the U.S. as a whole reported above.

The fact that the overall national economic impacts of the two carbon tax cases are negative does not mean that some groups would not gain. Specifically, the national results do not reflect the substantial distributional impacts in which some sectors, regions, and individuals would be adversely affected more than the average, while others would have lower impacts than average and, indeed, some would be better off than in the Baseline. Aggregate economic analyses such as this are sometimes incorrectly criticized for ignoring employment and other economic gains to lower-carbon activities; however, these gains *are* accounted for in this analysis. Employment gains in lower-carbon activities, and in the investments to reduce the economy's carbon-intensity, are embedded in the summary impact measure for labor as a whole; if these gains had not been included, the projected net employment impacts would have been more negative. Information on potential distributional impacts of the carbon tax cases is more apparent in the detailed sectoral and regional results that are provided in the rest of this report.

The results also indicate a trade-off between reducing carbon emissions in the U.S. and the cost to U.S. households. The lower carbon tax case reduces 2053 U.S. carbon emissions by about 31% relative to 2005 levels at an average cost per household over the entire period of about $310. The higher carbon tax case reduces U.S. carbon emissions in 2053 by about 71% relative to 2005 emissions, but the average cost per household is about $920 per household over the period. Thus, the results from these two carbon tax cases suggest that the potential fiscal benefits from the use of carbon tax revenues do not change the major potential trade-offs in carbon policy, which are that emissions reductions have a net cost and that deeper emissions cuts are increasingly costly.

I. INTRODUCTION

This report evaluates the effects of carbon taxes on the U.S. economy and energy sectors. The analyses assume that carbon tax revenues are used both to reduce the Federal debt and to reduce PIT rates.

A. Background

A carbon tax is a tax imposed on CO_2 and possibly other greenhouse gas emissions. Emissions of CO_2 are due largely to the combustion of fossil fuels in electricity production, transportation, heating, and various industrial and commercial processes. To reduce the administrative difficulties of monitoring CO_2 emissions and collecting the tax, the most direct method is to impose the tax "upstream" on producers of fossil fuels—including coal, natural gas, and various petroleum products—rather than "downstream" on the emissions themselves. Thus, a carbon tax would increase the cost of fossil fuels, leading to increases in costs to consumers and businesses as well as other economic impacts.

The increased costs due to a carbon tax would encourage companies to switch to lower-emitting fuels and would lead households and companies to reduce energy use. The net effect of these changes due to the carbon tax would be to reduce CO_2 emission. The greater the carbon tax, the larger these effects would be and thus the greater the reductions in CO_2 emissions would be.

B. Objectives of This Report

The principal overall objective of this report is to provide estimates of the effects of potential carbon taxes on the U.S. economy. That is, we consider the potential effects of a carbon tax on U.S. GDP and other measures of economic activity, compared to a Baseline case that does not have that carbon tax. We use a state-of-the-art integrated energy and economic model, the N_{ew}ERA model, to estimate these complex effects. The N_{ew}ERA model allows us to estimate detailed effects on energy markets as well as impacts on different sectors and different regions of the country.

As described in more detail in Section II, we consider two potential carbon tax cases:

1. **$20 Tax Case**: This case assumes a carbon tax that begins at $20/metric ton of CO_2 (2012 dollars) in 2013 and increases at 4% per year in real (2012) dollars.
2. **80% Reduction Tax Case**: This case is the same as the $20 Tax Case up through 2018, after which time it is assumed to be set on a trajectory designed to target progress towards an 80% reduction in CO_2 emissions from 2005 levels by 2053, but with a maximum tax rate set at $1,000/metric ton.

These cases were chosen based upon prior studies and proposals. The $20 Tax Case is similar to a case developed by the Congressional Budget Office (CBO) recently and is similar to other recent studies. The 80% Reduction Tax Case is consistent with the emission reduction objectives expressed in international climate negotiations and in prior Congressional cap-and-trade proposals.

One important determinant of the effects of a carbon tax is use of carbon tax revenue. Our study assumes that net carbon tax revenue would be used for two purposes: (1) to reduce the Federal debt (relative to the Baseline levels projected for each year); and (2) to reduce Federal PIT rates.

C. Outline of the Report

The remainder of the report is organized as follows. Section II provides an overview of the key assumptions associated with the Baseline case and the two carbon tax cases analyzed against that Baseline. It also provides an overview of the N_{ew}ERA model that is used to analyze these cases. Section III presents the results of the analyses. The appendices provide details on the N_{ew}ERA model, modeling assumptions, and detailed regional results.

II. CARBON TAX CASES, BASELINE, AND METHODOLOGY

This section provides an overview of the carbon tax cases evaluated in this report and the methodology we use to evaluate their effects on the economy and on the energy system. The section includes an overview of the N_{ew}ERA model as well as the various assumptions and methodologies we used to model the effects of the carbon tax cases.

A. Carbon Tax Cases

This section summarizes the carbon cases we evaluated, including the carbon tax rates and the assumptions regarding the uses of carbon tax revenues.

1. Carbon Tax Rates

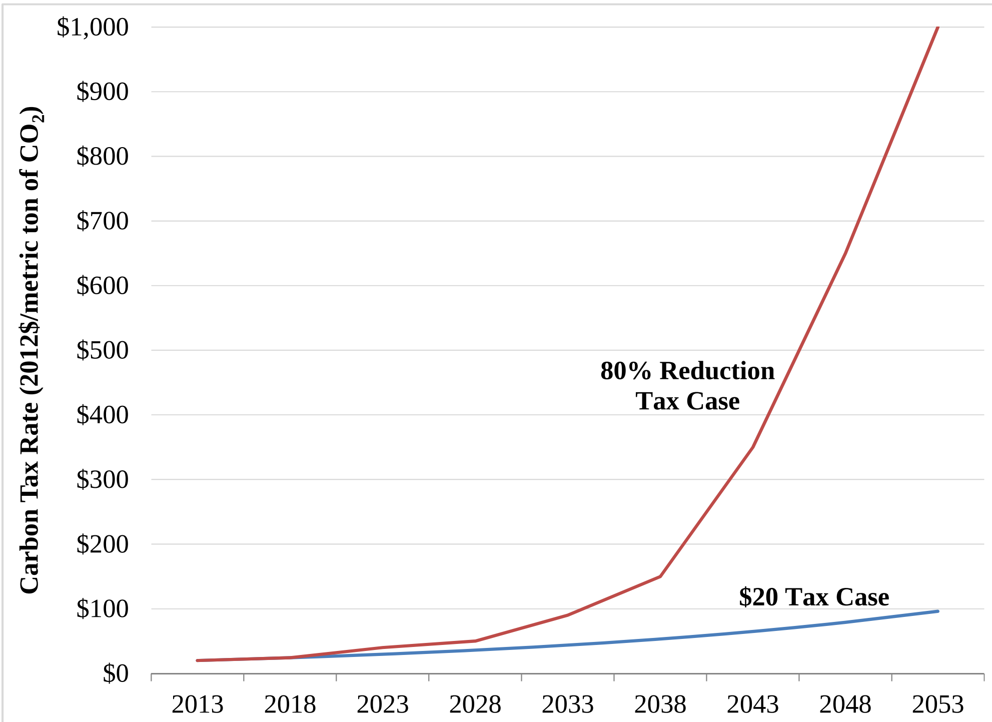
We evaluated two different carbon tax cases that differ substantially in the carbon tax rates over the entire modeling period (2013 to 2053).

1. **$20 Tax Case**: The first case assumes that a policy is enacted that imposes a $20 tax per metric ton of CO_2 (in 2012 dollars) starting in 2013. The carbon tax increases over time at a rate of 4% in real terms.
2. **80% Reduction Tax Case**: The second case begins just like the first with the same carbon tax rates up until 2018. This case assumes that the carbon tax rate increases after 2018 to levels needed to put U.S. CO_2 emissions on the path towards an 80% reduction by the end of the model horizon (2053), a target similar to the objectives discussed in international negotiations and included in prior Congressional cap-and-trade proposals.[8] The 80% reduction is not completely achieved by the end of the model horizon because of a constraint that the carbon tax rate not exceed $1,000 per metric ton of CO_2 (in 2012 dollars).

The carbon taxes for the two cases are shown in Figure 8. The rates are identical in 2013 and 2018, but begin to diverge thereafter as the 80% Reduction Tax Case includes a path towards an 80% reduction in emissions relative to 2005 CO_2 emissions.

[8] For example, the Waxman-Markey Bill (H.R. 2454) passed by the U.S. House of Representatives in June 2009, would require greenhouse gas emission reductions of 83% relative to 2005. It should be noted, however, that the Waxman-Markey Bill and other similar legislative proposals allowed for international offsets and had provisions for the banking of allowances.

Figure 8: Carbon Tax Rates (2012$/metric ton of CO_2)



2. Carbon Tax Revenues

The imposition of the carbon tax results in additional net tax revenues for the Federal government. Gross carbon tax revenues are equal to the carbon tax rate multiplied by the annual emissions of CO_2 resulting from the combustion of fossil fuels such as coal, natural gas, and oil. Net carbon tax revenues reflect lower federal revenues in other areas due to the negative economic impacts of the carbon tax. Under both scenarios, the net revenue from a carbon tax would be used for debt reduction and to lower individual tax rates.

1. **Reduction of Federal Debt**: Until 2023, all of the net carbon tax revenues would be used to lower the Federal debt. After 2023, 50% of the net carbon tax revenues are used to lower the Federal debt, while the other 50% is used to defray increases in income tax rates (see point 2). Lowering the federal debt would lower interest rates for government borrowing, which would reduce the cost to the economy to service the debt.
2. **Reduction of Federal PIT Rates**: In the Baseline, the 2012 capital and labor tax rates are assumed to remain in effect until the debt/GDP ratio exceeds 1.0, at which point the model assumes tax rates would increase to pre-2001 levels.[9] Thus, the higher tax rates come into effect starting in model year 2023. At that time, it is also assumed that 50% of the net carbon tax revenues are used to moderate the amount of increase in Federal PIT

[9] These baseline tax rates include all of the tax cuts enacted from 2001 through 2003 on capital and labor income and the lowered payroll tax rate that was in effect only in 2011 and 2012.

rates that occurs in the Baseline.[10] Reduction of PIT rates relative to their baseline levels reduces the baseline tax distortions which offsets some of the economic costs of the carbon tax.

In the policy scenarios, the flow of goods and services from the government is assumed to be the same as in the Baseline. That is, we do not assume that the new carbon tax revenues will be used to increase government spending or that the carbon policy will be paid for by reduced government services.[11] However, the carbon tax does affect consumption, investment, and labor market decisions, which results in lower Federal revenues from taxes on capital and labor. Thus, benefits of debt and tax rate reduction from use of carbon tax revenues only occur after a sufficient portion of the new carbon tax revenues is used to replace revenue shortfalls from the effect of the carbon tax itself on Federal taxes on capital and labor. Thus, the amounts used for debt and tax rate reduction, as described above, are the *net* amount after offsetting reductions in other Federal revenue projected for each carbon tax case.

B. N_{ew}ERA Model

The N_{ew}ERA model is an economy-wide integrated energy and economic model that includes a detailed representation of the electricity sector. It has been designed to assess, on an integrated basis, the effects of major policies on electricity, other energy markets, and the overall economy. The model performs its analysis with regional detail, accounting for over 30 electricity market regions and 11 regions for other economic activities. Figure 9 provides an overlay of the electricity market region boundaries and the macroeconomic region boundaries. Each colored area on the map denotes a separate electricity market region, and the acronyms that identify each electricity market region are shown in black letters. Note that electricity market regions do not always follow state borders. The macroeconomic region boundaries (which do follow state borders) are denoted by the white lines, and their identifying acronyms are shown in white lettering (and further defined in Figure 10 below). Appendix A provides separate maps of the electricity and macroeconomic regions. This overlay format can be useful to those who wish to understand the mapping between specific electricity market regions (which include the supply conditions that determine electricity costs) and the macroeconomic regions of the analysis (which include the consumers and businesses that have to pay for electricity). As can be seen, it is not a simple one-to-one mapping.

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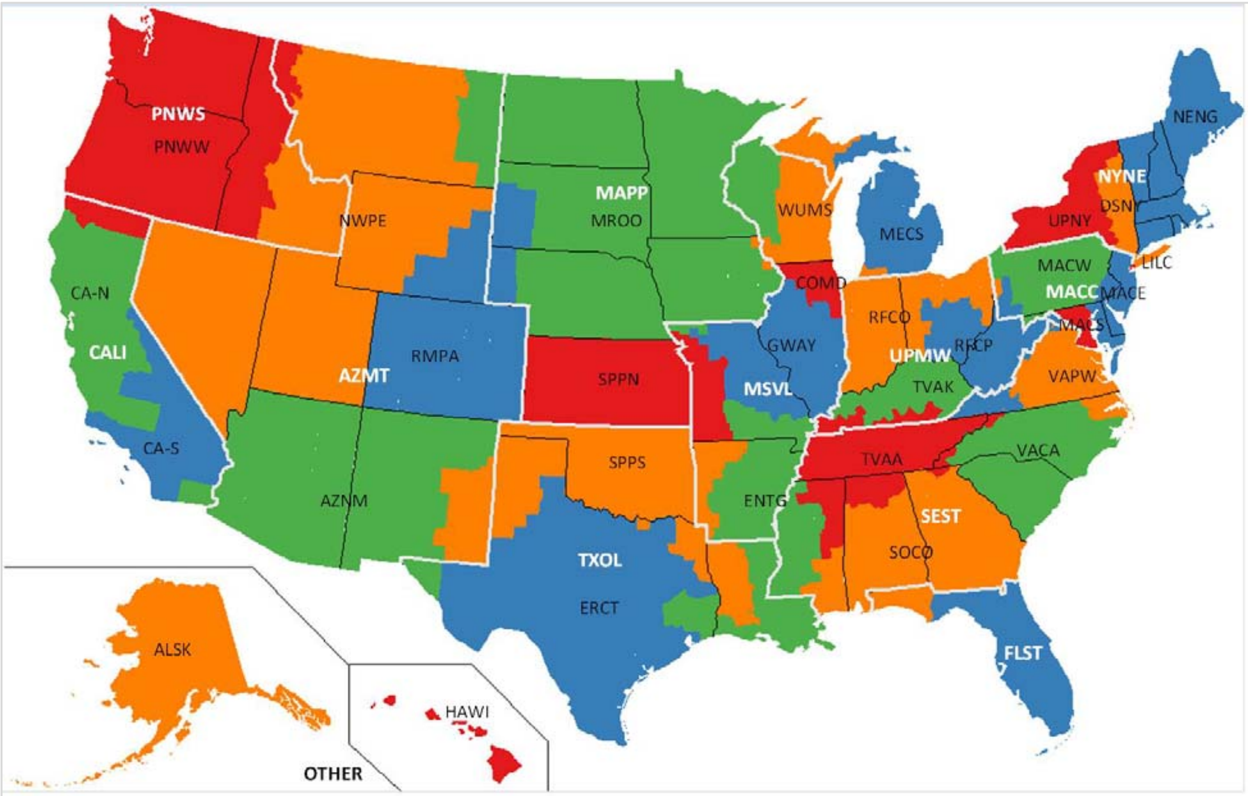
[10] In both of our policy scenarios, even though 50% of net carbon revenues after 2023 are dedicated to lower tax rates, PIT rates would still be higher than the 2012 rates (although lower than their baseline levels).

[11] These assumptions are necessary to ensure that the consumer welfare associated with government services (which is not directly calculated in the model) is identical in both the Baseline and the carbon tax cases. Most prior climate cap-and-trade bills have proposed a variety of new government spending programs, but we are not aware of any specific government spending proposals for carbon tax policies. Moreover, analytical methods to account for their impacts on the economy would need to be developed before they could be incorporated into the analysis. Until specific spending proposals are put forth as part of a specific carbon tax proposal, it is reasonable to avoid the additional analytical effort their analysis would require.

Appendix A also provides a detailed description of the N_{ew}ERA model structure, logic, and other key inputs.

Figure 9: N$_{ew}$ERA Regional Map



One of the primary drivers of the differences in regional impacts (reported in Section III) is the difference in carbon intensity (metric tons of CO_2 per thousand dollars of economic output), as shown in Figure 10. The differences in carbon intensity are caused by differences in industrial composition (*e.g.*, California has less heavy industry), electricity generation mix (*e.g.*, California and New York/New England have limited coal-fired generation), and relative energy prices (*e.g.*, a $20 carbon tax in California is a smaller percentage increase in energy prices than in many other regions so the tax has a smaller impact in California).

Figure 10: Baseline Carbon Intensity by Region in 2013

Region	Average Emissions Intensity
Upper Midwest (UPMW)	0.23
Texas, Oklahoma, Louisiana (TXOL)	0.17
Mid-America (MAPP)	0.16
Arizona and Mountain States (AZMT)	0.16
Mississippi Valley (MSVL)	0.13
Southeast (SEST)	0.12
Mid-Atlantic (MACC)	0.10
Florida (FLST)	0.09
Pacific Northwest (PNWS)	0.09
California (CALI)	0.07
New York/New England (NYNE)	0.06

The N_{ew}ERA model is a long-term model that includes the assumption that households and firms develop optimum decisions over the modeling period, with perfect foresight. For this analysis, we evaluate the economic implications of the carbon tax cases over the period from 2013 through 2053. The model develops results for every five year period beginning with 2013. Thus the model provides results for 2013, 2018, 2023, 2028, 2033, 2038, 2043, 2048, and 2053. In this report we show the results in ten year increments.

C. Development of Key Modeling Elements

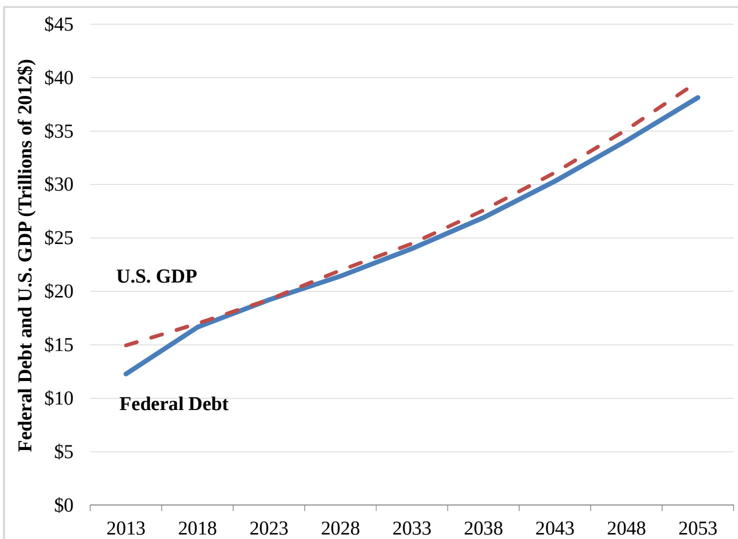
The following sections provide information on the various modeling elements. Appendix B and Appendix C provide additional details on these elements.

1. Developing the Model Baseline

There are many assumptions that define the Baseline case and are also important in determining the ultimate costs and consequences resulting from the scenarios. Wherever possible, we have used publicly-available assumptions from sources like the Energy Information Administration's (EIA's) *Annual Energy Outlook 2012* (AEO 2012), the U.S. Environmental Protection Agency (EPA), and the CBO.

For purposes of this analysis, one of the most important assumptions is the Baseline case's level of Federal debt, which is a function of factors such as government tax revenues and government transfers and expenditures. For the years 2013 through 2022, the Baseline scenario follows the assumptions of the "Extended Alternative Fiscal Scenario" in the CBO 2012 long-term budget outlook.[12] That is, the tax rates in effect in 2012 remain in effect, and spending behavior remains similar to today's pattern. However, for our Baseline we also assume that this pessimistic CBO scenario cannot be sustained indefinitely. We therefore assume that annual deficits will start to be reined in when the Federal debt reaches 100% of GDP, thus slowing growth of the debt so that the Baseline case's debt never exceeds 100% of GDP once it gets to that level. This is accomplished by making two adjustments to the assumptions of the CBO "Extended Alternative Fiscal Scenario." First, Federal tax rates are immediately increased to levels consistent with tax rates in the CBO "Extended Baseline Scenario."[13] This tax rate increase is not, on its own, sufficient to achieve a baseline debt/GDP ratio of 1.0. Thus, the second adjustment to the assumptions of the CBO "Extended Alternative Fiscal Scenario" is to reduce its projections of government expenditures sufficiently to meet the debt/GDP ratio target.[14] The first model year in which these two adjustments are made is 2023. Figure 11 shows the baseline assumption regarding the Federal debt (the blue line), relative to the GDP (the dashed red line).[15]

Figure 11: Baseline Federal Debt



The model accounts for the following categories of Federal taxes: PIT rate on capital, PIT rate on labor, payroll taxes collected for Social Security under the Federal Insurance Contributions Act (FICA) and for Medicare hospital insurance (HI), and the corporate tax rate. The model also

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[12] *The 2012 Long-Term Budget Outlook*, June 2012, Congressional Budget Office, available at: http://www.cbo.gov/publication/43288.

[13] "Extended Baseline Scenario" in the CBO report is equivalent to assuming that all of the pre-2001 tax levels come into effect again.

[14] These reductions are not as large as those in the "Extended Baseline Scenario" of the CBO report, which projects a debt/GDP ratio well below 1.0.

[15] To be clear, our baseline tax rates from 2013 until 2022 are all kept at the rates that were prevailing during 2012, and do not include any of the tax rate increases that occurred on January 1, 2013.

includes state PIT and corporate tax rates. More details about the Baseline tax rate assumptions are provided in Appendix B. The model includes all of the tax rates listed above to simulate the magnitude of the overall tax interaction effect with carbon taxes. However, the only rates among these that are reduced in the carbon tax cases due to recycling of carbon tax revenues are the Federal PIT rates (both the capital and labor rates). Further, such reductions only occur in model years from 2023 onwards, when the respective Baseline rates are at their pre-2001 levels. The magnitude of those Federal PIT rate changes relative to the Baseline Federal PIT rates is not an assumption, but a carbon case result that is described in the results section of this report.

Fuel prices are an important input because of the different carbon content of fuels and the opportunities for fuel switching, primarily in the electricity sector. Natural gas and crude oil prices are based on the AEO 2012 Reference Case.[16] Supply curves for coal are based on information from the U.S. EPA.[17] Capital costs and operating characteristics of new electricity generating technologies, electricity demand growth, GDP growth, and non-electricity sector fuel consumption and emissions are also based on assumptions in AEO 2012.

The availability of new low-carbon electricity generating technologies such as nuclear and carbon capture and storage (CCS), with either coal or natural gas, is a baseline assumption that is more relevant in the policy scenario (with the imposition of the carbon tax). NERA imposed realistic adoption rates for these technologies based on historical rates of adoption of nuclear and other developing technologies.

The $\mathrm{N_{ew}}$ERA model includes several alternative transportation fuels for the personal vehicle and commercial trucking sector. The fuels for the personal vehicle market are assumed to be replacements for gasoline, while those for the trucking market are substitutes for diesel. For the gasoline market, we include three different types of ethanol and compressed natural gas (CNG).[18] To reflect the range of possible emission reductions and most likely ethanols we include corn-based ethanol, sugar-based ethanol, and cellulosic ethanol. For the diesel market, we include liquid fuels – soy-based diesel and low-carbon diesel – as well as CNG. Whether or not these fuels replace conventional fuels depends on the relative cost of these fuels compared to their conventional counterparts. In the Baseline, the relative cost of fuels depends on their production and infrastructure costs.

In the tax cases, however, the relative emissions intensity of each fuel matters because a carbon tax raises the cost of each fuel based on the amount of carbon emitted per unit of energy. As the carbon tax increases, the alternative transportation fuels become more cost-effective relative to their conventional fuel counterparts.

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[16] Available at: http://www.eia.gov/forecasts/archive/aeo12/index.cfm.

[17] Appendix 9-4 Coal Supply Curves in EPA Base Case V.4.10.

[18] EVs are another possible technological response. EVs were not included in this analysis due to time constraints. However, previous experience with modeling EVs suggests they would not become economical except in the higher carbon tax case, and only in the later parts of the analysis horizon.

2. Modeling the Carbon Tax Cases

In the tax cases, the only changes were the imposition of the carbon taxes, the uses of net carbon tax revenues, and the effects of changes in the debt on interest rates. All other assumptions remain the same as in the Baseline. However, variables like fuel prices, electricity demand, and GDP growth change in response to the carbon taxes. These changes are presented in the Results section.

3. Modeling Uses of Carbon Tax Revenue

Including an evaluation of the economic impacts of the uses of net carbon revenues from a carbon tax policy is one of the key features of this study's analysis of carbon tax policies. There are many ways that a carbon tax's revenues could be used, and thus returned ("recycled") to the economy. Two primary uses of carbon tax revenues have been important in recent policy discussions: (1) reduce existing tax rates on capital and/or labor (without affecting the debt); and (2) reduce the Federal debt (relative to what it would otherwise be without the carbon tax).

1. Using carbon tax revenues to reduce other taxes seems appealing because existing capital and labor taxes create distortions that reduce the supply of capital and labor and thus reduce overall productive activity. Using carbon tax revenues to reduce these tax rates ("tax swap") would reduce these distortions. Put another way, a carbon tax combined with such a "tax swap" offers the potential to raise the same total Federal revenues but in a manner that could reduce distortions related to supply of capital and labor.[19] However, as discussed in the next section, the carbon tax leads to distortions of its own, including interactions that exacerbate distortions in labor and capital taxes, and thus the combined effect of the "tax swap" on the overall productivity of the economy is the net result of both positive and negative effects.
2. Using carbon tax revenues to reduce the Federal debt relative to its baseline levels is appealing because this could reduce the interest rate for Federal borrowing (see Section 5 below). This effect would reduce interest payments on the Federal debt that remains. Since much of the Federal debt is financed from abroad, reducing federal debt payments would result in additional income to U.S. households. Thus, as with a tax swap, using a carbon tax's revenues for debt reduction could mitigate the net cost of the carbon tax policy.[20]

[19] In economic analysis circles, the term "double dividend" is used to refer to the fact that reductions in economic distortions from lowered marginal capital and/or labor taxes produce a second return (or "dividend") from a carbon-pricing policy (the first "dividend" being emissions reductions that the policy in intended to motivate). Goulder (1995) distinguished between a "weak" and a "strong" double dividend. If the reduced economic distortions due to the reduction in marginal capital and/or labor taxes would be smaller than the costs of the carbon-pricing policy—including the additional distortions due to the carbon tax—so that the carbon policy still has a net economic cost, this is referred to as a "weak double dividend." If the reduced economic distortions would be larger than the costs of the carbon-pricing policy, this is referred to as a "strong double dividend."

[20] The logic of offsetting economic benefits of deficit reduction is parallel to the concept of a double dividend, but this term has not traditionally been applied to use of carbon revenues to reduce deficits. Whether the benefits of deficit reduction will be greater or less than the direct cost of a carbon-pricing policy is not only uncertain, but we

While there are any number of possible combinations of revenue recycling options that could be paired with a carbon tax policy, this analysis has considered only the single combination summarized above. We make no suggestion that this particular combination is desirable, politically likely, or that it will produce the best overall policy outcomes. It simply reflects a blend of the two policy options currently prominent in discussions of revenue recycling in a possible carbon tax policy. Modeling of other revenue recycling alternatives would be necessary to assess their potential economic impacts.

As described above, this analysis applies the net carbon tax revenue to lowering the Federal debt and lowering Federal PIT rates. The N_{ew}ERA model begins with baseline assumptions regarding Federal deficits over time (and the resulting Federal debt in each future year) as well as Federal PIT rates (see Appendix B). Within the N_{ew}ERA cases, the net carbon tax revenues are estimated, then divided between the two uses as follows: net carbon tax revenues are used entirely for debt reduction from 2013 through 2022, and are evenly split between debt reduction and PIT rate reduction from 2023 onwards. Thus, no tax swap occurs in our policy cases until tax rates are raised above their 2012 levels. Despite the 50% of net carbon revenues that are used to defray tax rate increases from 2023 onwards in the two carbon tax cases, PIT rates remain above their 2012 levels in all those years.

4. Modeling Net Carbon Revenues

In the carbon tax cases, total carbon tax revenues are calculated as the product of the carbon tax rate in a particular year and the resulting emissions of CO_2 from the combustion of fossil fuels. Not all these revenues are available to lower the Federal debt or lower Federal PIT rates, however, because a carbon tax (like any other tax) has a negative impact on economic activity of its own (its "deadweight loss" or impact on economic efficiency) that reduces federal tax payments and thus reduces the net carbon tax proceeds that would be available for revenue recycling. Since the burden of the carbon tax reduces labor earnings and capital earnings, Federal tax revenues from those existing tax bases decline relative to what they are in the Baseline, *even with baseline spending and tax rates*. That is, the carbon tax itself worsens the debt relative to the Baseline (without the carbon tax). Thus, a portion of the gross carbon tax revenues must first be used just to get the debt back to the Baseline's levels.

As PIT rates are reduced from their baseline levels to provide for the carbon policy's tax swap that further affects the revenues from existing taxes. This additional shift in each year's deficit (and hence debt level) relative to that of the Baseline also must be accounted for when determining how much *net* carbon tax revenue is available to reduce debt while providing for a PIT rate reduction of an equal dollar amount in terms of reduced PIT tax collections.[21] These

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are not aware of any other modeling studies of the economic impact of using a carbon tax specifically for deficit reduction benefits.

[21] The reduction in PIT rates has two effects on the deficit: (1) direct reductions in tax revenues per dollar of taxable income, and (2) indirect increases in taxable income as a result of increased supply of labor and capital, and a smaller tax interaction effect from the policy. As discussed above in the context of the "weak double dividend,"

complex computations are solved in a simultaneous, general-equilibrium manner in the N_{ew}ERA model's solution.

5. Modeling the Effects of Reductions in Federal Debt on Interest Rates

As discussed above, one of the economic benefits associated with using net carbon tax revenues to reduce the Federal debt is that a lower debt is assumed to lead to a lower interest rate for Federal government borrowing, and therefore, lower debt service payments. We assume that Federal debt is financed by borrowing from foreign entities. Thus, the reduced interest payments in the carbon tax cases represent a windfall of increased wealth to U.S. consumers, which was wealth that was presumed to be sent outside of the U.S. economy in the Baseline.

We have done an extensive literature review of the relationship between government debt and interest rates, as discussed in Appendix C. For purposes of this analysis, we assumed that a change in government debt equal to 1% of GDP would result in a change in the long-term interest rate of 3 basis points. This assumption is largely based on Engen and Hubbard (2005). We rely upon this study for several reasons – their conclusions are grounded in economic theory, backed by empirical results, and consistent with historical experience. The study is relatively recent and includes a comprehensive review of the literature on the relationship between government debt and interest rates. The result that debt has a small positive effect on long-term interest rates seems more plausible than assumptions of either no effect of government debt (which many economists would say is inconsistent with theory) or a large effect (which is arguably inconsistent with historical experience). Note, however, that the effects of changes in the debt-to-GDP ratio on interest rates are subject to considerable debate, as the literature review we provide in Appendix C reveals.

the indirect effect diminishes the size of the deadweight loss of the carbon tax and decreases the deficit, while the direct effect leads to a greater deficit. The net effect of these two effects must also be accounted for—in the general equilibrium context—when determining how much of the gross carbon tax revenues will remain to improve the deficit position relative to the Baseline levels.

III. STUDY RESULTS

The addition of carbon taxes to the Baseline creates additional costs to the U.S. economy. The carbon taxes add to the costs of energy use because the tax is applied to the sale of fossil fuels that emit carbon. Thus, the costs of consuming coal, natural gas, and petroleum products (*e.g.*, gasoline) increase. The increases in energy costs ripple through the economy and result in higher costs of production and less spending on non-energy goods. The economic impacts of these cost increases are at least partially offset by the effects of the manner in which the carbon tax revenues are used, which we assume is for reductions in the Federal debt and PIT rates. Lowering the debt results in lower costs to service the debt, while lowering PIT rates reduces the distortionary impacts of these taxes.

A. Impacts on the U.S. Economy

1. Gross Domestic Product and Its Components

GDP is an economic measure of the entire economy. The components of GDP are consumption, investment, government spending and net exports. Since the level of Federal government expenditures is assumed to remain constant, the changes in GDP are driven by changes in consumption, investment, and net exports. Figure 12 shows the estimated changes in GDP and its components in the two carbon tax cases. GDP declines by approximately 0.5% per year for the $20 Tax Case, while the GDP reduction for the 80% Reduction Tax Case increases from 0.4% in 2013 to nearly 4% by 2053. Both consumption and investment decline as well.

Figure 12: Gross Domestic Product and Components (Percentage Change from Baseline)

	2013	**2023**	**2033**	**2043**	**2053**
GDP					
Baseline (Billions)	$14,940	$19,400	$24,680	$31,280	$38,120
$20 Tax Case	-0.4%	-0.5%	-0.5%	-0.5%	-0.6%
80% Reduction Tax Case	-0.4%	-0.5%	-1.0%	-2.5%	-3.6%
Consumption					
$20 Tax Case	0.0%	-0.3%	-0.4%	-0.4%	-0.5%
80% Reduction Tax Case	-0.1%	-0.7%	-0.9%	-1.6%	-2.6%
Investment					
$20 Tax Case	-2.7%	-1.0%	-1.2%	-1.3%	-1.5%
80% Reduction Tax Case	-2.0%	-0.4%	-2.3%	-7.4%	-9.4%
Net Exports					
$20 Tax Case	0.6%	0.4%	0.9%	0.9%	0.9%
80% Reduction Tax Case	0.2%	1.1%	1.9%	3.8%	5.0%

One common economic metric of policy costs is the change in consumption per household (sometimes described as change in costs per household). It is important to note that, as with the other measures, the estimated change in consumption per household is a comprehensive figure that includes a large number of influences. This metric incorporates the financial benefits to consumers from the recycling to them of all net carbon tax revenues. It also takes into account the many ways in which consumers and producers can change their behavior to limit financial losses from the increases in energy and other prices due to the carbon tax. That is, this impact measure includes cost-minimizing adjustments to consumers' "market basket" of goods and services purchased and to their lifestyle/behavioral patterns.[22] Similarly, the loss in consumption per household incorporates all the adjustments to inputs and production processes that businesses make to minimize the effects of the carbon tax on the cost of their products or services. These adjustments can lead to non-financial losses and thus the change in consumption per household is not a complete measure of consumer losses. The full effects of the carbon tax include the qualitative effects of all such changes in personal choices and activities as well as the financial costs we report here.

In this study, we report reduced consumption per household as a dollar value relative to current average consumption levels to make it easier for readers to put these estimates into context with current household consumption and income. Figure 13 shows the change in consumption per household for the $20 Tax Case for individual regions and the U.S. as a whole in selected model years and on average as a present value over the model horizon. On average, U.S. household consumption declines by $20 in 2013, a negative impact that increases to $440 by 2053.[23] Regions fare better or worse than the U.S. average primarily due to each region's relative carbon intensity, which is a significant determinant of the increases in costs that consumers in a region will experience as a result of the carbon tax.

Figure 14 includes the change in consumption per household for the 80% Reduction Tax Case. The higher carbon taxes over time produce substantially larger losses in consumption than in the $20 Tax Case in the later years.[24] On average for the 80% Reduction Tax Case, U.S. household consumption declines by $80 in 2013, which increases to almost $2,700 by 2053.

[22] One prominent example at the personal level is use of personal vehicles for transportation services. The carbon tax cases involve people driving fewer miles and buying different types of cars than in the Baseline.

[23] These changes in consumption are relative to an average Baseline national household consumption of $94,000. We estimate that the *median* consumption level is about $65,000, although this is an estimate that is not directly used by N_{ew}ERA.

[24] The two tax cases have different impacts prior to 2023 even though the carbon prices are the same in those years because the model assumes perfect foresight. Therefore, decisions made in 2013 and 2018 are made with the full awareness that carbon prices are going to be significantly higher in the 80% Reduction Tax Case than in the $20 Tax Case starting in 2023, and this drives different optimal economic decisions in 2013 and 2018.

Figure 13: Change in Consumption per Household - $20 Tax Case

Region	Present Value	2013	2023	2033	2043	2053
Arizona and Mountain States	-$950	-$840	-$970	-$950	-$1,010	-$1,040
California	-$60	$310	-$90	-$120	-$250	-$230
Florida	-$30	$270	-$60	-$50	-$150	-$140
Mid-Atlantic	-$400	-$20	-$460	-$470	-$580	-$590
Mid-America	-$450	-$290	-$480	-$450	-$540	-$560
Mississippi Valley	-$300	-$70	-$330	-$330	-$420	-$410
New York/New England	$30	$590	$10	-$20	-$180	-$170
Pacific Northwest	-$200	$30	-$240	-$240	-$300	-$320
Southeast	-$350	-$130	-$400	-$380	-$450	-$450
Texas, Oklahoma, Louisiana	-$290	-$30	-$300	-$310	-$400	-$420
Upper Midwest	-$660	-$530	-$710	-$690	-$730	-$750
U.S.	**-$310**	**-$20**	**-$340**	**-$350**	**-$440**	**-$440**

Present value calculated using a 5% real discount rate.

Figure 14: Change in Consumption per Household – 80% Reduction Tax Case

Region	Present Value	2013	2023	2033	2043	2053
Arizona and Mountain States	-$1,950	-$1,480	-$1,700	-$1,850	-$2,470	-$3,390
California	-$640	$510	-$340	-$590	-$1,490	-$2,890
Florida	-$300	$540	-$110	-$230	-$770	-$1,990
Mid-Atlantic	-$1,120	-$30	-$820	-$1,060	-$1,910	-$3,450
Mid-America	-$1,110	-$520	-$900	-$1,050	-$1,590	-$2,550
Mississippi Valley	-$750	-$70	-$560	-$730	-$1,200	-$2,210
New York/New England	-$530	$950	-$150	-$440	-$1,500	-$3,190
Pacific Northwest	-$890	-$140	-$670	-$820	-$1,440	-$2,540
Southeast	-$810	-$140	-$670	-$760	-$1,200	-$2,220
Texas, Oklahoma, Louisiana	-$1,270	-$610	-$1,040	-$1,180	-$1,810	-$2,800
Upper Midwest	-$1,190	-$710	-$1,070	-$1,160	-$1,510	-$2,350
U.S.	**-$920**	**-$80**	**-$690**	**-$860**	**-$1,510**	**-$2,680**

Present value calculated using a 5% real discount rate.

2. Labor Market

Figure 15 includes labor impacts due to the carbon taxes (and resulting changes in Federal PIT rates). The wage rate declines as the carbon tax rate increases because of lower demand for labor as companies have higher costs and lower output. Labor income is a function of the wage rate and the quantity of hours devoted to labor (as opposed to leisure). Across the cases, labor income experiences declines that are greater than or equal to the declines in the wage rate. A larger decline in the labor income than the wage rate implies that workers are working fewer hours, which is a response to the lower wage rate (smaller incentive to work).

The labor income change in Figure 15 can also be stated in terms of job-equivalents, by dividing the labor income change by the annual income from the average job. A loss of one job-equivalent does not necessarily mean one less employed person—it may be manifested as a combination of fewer people working and less income per person who is working. However, this measure allows us to express employment-related impacts in terms of an equivalent number of employees earning the average prevailing wage.

Figure 15: Labor Impacts

	2013	2023	2033	2043	2053
$20 Tax Case					
Wage Rate (% Change from Baseline)	-0.8%	-1.0%	-0.9%	-1.1%	-1.2%
Labor Income (% Change from Baseline)	-1.0%	-1.1%	-1.1%	-1.2%	-1.4%
Job-Equivalents* (Change from Baseline, Thousands)	-1,510	-2,290	-2,520	-3,210	-3,770
80% Reduction Tax Case					
Wage Rate (% Change from Baseline)	-0.6%	-1.2%	-1.7%	-4.3%	-7.2%
Labor Income (% Change from Baseline)	-0.8%	-1.3%	-1.9%	-5.1%	-8.3%
Job-Equivalents* (Change from Baseline, Thousands)	-1,260	-2,750	-4,370	-11,860	-20,670

* Total job-equivalents equals total labor income change divided by the average annual income per job. This does not represent a projection of numbers of workers that may need to change jobs and/or be unemployed, as some or all of it could be spread across workers who remain employed.

3. Federal Tax Collections, Deficits and Debt

Our analysis finds that the net carbon tax proceeds available for reducing federal PIT rates and debt reduction are substantially less than the gross projected carbon tax revenues. Figure 16 summarizes the results for the $20 Tax Case and Figure 17 for the more costly 80% Reduction Tax Case. Note that the results presented in these figures are simultaneously determined so that the final amount used to improve each year's deficit (row 3) is equal to the amount by which the scenario's PIT rate reductions decrease the carbon case tax collections (row 5), and they are both also consistent with the general equilibrium conditions that determine the carbon tax's deadweight loss (row 2). Thus, any change in the rule for sharing net carbon revenues between the objectives of debt reduction and tax rate reduction also will change the amount of net carbon revenues available, and cannot be estimated without a separate model run.

Figure 16: Carbon Tax Revenues and Their Disposition in the $20 Tax Case

	2013	2023	2033	2043	2053
(1) Gross Carbon Tax Revenue (Billions)	$104	$138	$201	$301	$395
(2) Reductions in Existing Federal Tax Revenues Due to Deadweight Cost of Carbon Tax (Billions)*	$43	$51	$74	$104	$145
(3) Reduction from Baseline Deficit for that Year (Billions)	$61**	$44	$64	$98	$125
(4) PIT Rate Reduction from "Carbon Tax Swap" (%)	0%**	1.5%	1.7%	2.1%	2.1%
(5) Reduction in Tax Collections Due to PIT Rate Reduction (Billions)	$0**	$44	$64	$98	$125

* Combines effects of reduced taxable income due to deadweight loss of carbon tax and improvements in deadweight loss due to reduced PIT rates shown in row (4). Does not include reductions in PIT revenues due directly to reductions in PIT rates, which are reported in row (5).
** 100% of net carbon tax revenue goes to deficit/debt reduction until baseline tax rates are increased above their prevailing 2012 levels, starting in 2023.

Figure 17: Carbon Tax Revenues and Their Disposition in the 80% Reduction Tax Case

	2013	2023	2033	2043	2053
(1) Gross Carbon Tax Revenue (Billions)	$104	$176	$325	$906	$1,764
(2) Reductions in Existing Federal Tax Revenues Due to Deadweight Cost of Carbon Tax (Billions)*	$42	$57	$112	$429	$910
(3) Reduction from Baseline Deficit in that Year (Billions)	$62**	$60	$107	$239	$427
(4) PIT Rate Reduction from "Carbon Tax Swap" (%)	0%**	2.1%	2.9%	5.3%	7.8%
(5) Reduction in Tax Collections Due to PIT Rate Reduction (Billions)	$0**	$60	$107	$239	$427

* Combines effects of reduced taxable income due to deadweight loss of carbon tax and improvements in deadweight loss due to reduced PIT rates shown in row (4). Does not include reductions in PIT revenues due directly to reductions in PIT rates, which are reported in row (5).
** 100% of net carbon tax revenue goes to deficit/debt reduction until baseline tax rates are increased above their prevailing 2012 levels, starting in 2023.

The tables above summarize the basic components determining the changes in the debt level in each year relative to the respective baseline debt levels. The projected annual deficits and associated debt levels that result are shown in Figure 18. These projections assume the same level of government spending in both carbon tax cases as in the Baseline, and the only difference in deficits and associated debt levels is due to changes in total Federal tax revenues, which is the sum of carbon tax revenues and revenues from all other existing Federal taxes. Relative to its baseline level, the Federal debt in 2053 is reduced by 8% in the $20 Tax Case and by 18% in the 80% Reduction Tax Case. In present value terms, the net economic benefit of a lower debt is tied to changes in the interest rate on Federal debt. In this analysis, the interest rate on Federal debt is assumed to vary with the debt-to-GDP ratio (see Appendix C). While the debt in 2053 is 18% lower in the 80% Reduction Tax Case, the debt-to-GDP ratio is only 14.2% lower, because GDP is estimated to decrease by 4% relative to baseline levels in 2053 (see Figure 12 above). The debt-to-GDP ratio is 7.5% lower by 2053 in the $20 Tax Case.

Figure 18: Federal Deficit and Debt Outcomes of Baseline and Two Carbon Tax Cases (Billions)

	2013	2023	2033	2043	2053
Baseline					
Deficit	$1,020	$330	$520	$720	$830
Debt	$12,280	$19,210	$24,010	$30,320	$38,130
$20 Tax Case					
Deficit	$960	$290	$450	$630	$700
Debt	$12,220	$18,540	$22,800	$28,290	$34,950
80% Reduction Tax Case					
Deficit	$950	$270	$410	$490	$400
Debt	$12,220	$18,510	$22,500	$27,170	$31,290

As noted above, we assume that Federal debt is financed by borrowing from foreign entities and thus the reduced interest payments in the carbon tax cases represent a windfall of increased wealth to U.S. consumers (wealth that was presumed to be sent outside of the U.S. economy in the Baseline). By incorporating this estimate of the financial gain from reduced interest rates into consumer income, the gains flow through to all of the other measures of economic impact reported in this study. By 2053, the lower borrowing cost increases consumer welfare relative to baseline welfare by $76 billion per year in the $20 Tax Case and by $129 billion per year in the 80% Reduction Tax Case.

4. Sectoral Output

Figure 19 shows the estimated changes in energy sector output for the two carbon tax cases. The changes in sectoral output reflect changes both in the quantity of output and changes in the prices/value of output. The value of output declines most markedly in the coal sector. Of the primary fossil fuels, coal has the highest carbon content. It is also primarily used in the electricity sector, where elevated coal prices due to the carbon tax cause generators to switch to natural gas in the short term and to renewable, nuclear and CCS generation in the longer term.

The refined petroleum products sector also sees a large decline in output relative to the Baseline. This is attributable to the higher gasoline prices (because of the carbon tax adder), which leads to declines in vehicle-miles travelled and increases in miles per gallon of the personal transportation fleet. There is also an increasing use of lower-carbon gasoline and diesel alternatives, which reduce demand for conventional gasoline and diesel.

The natural gas sector experiences both increases and decreases over the modeling horizon. In the near term, natural gas gains at the expense of coal in both cases; in the 80% Reduction Case, natural gas then becomes too expensive for the electricity sector leading to declines, which are mitigated around 2050 by increased natural gas usage in the production of lower carbon transportation fuel alternatives. Note that domestic crude oil output does not change substantially because prices are set in global markets. Because imports represent the crude oil that is supplied at the margin, the reduction in refined petroleum output is reflected in reduced crude imports.

Figure 19: Energy Sector Output (Percentage Change from Baseline)

	2013	2023	2033	2043	2053
Coal					
$20 Tax Case	-16%	-44%	-45%	-40%	-55%
80% Reduction Tax Case	-17%	-54%	-87%	-98%	-99%
Crude Oil					
$20 Tax Case	0.5%	-0.2%	0.1%	-0.1%	-0.1%
80% Reduction Tax Case	0.8%	-1.2%	-3.9%	-9.6%	-12%
Natural Gas					
$20 Tax Case	3.1%	0.8%	1.8%	-1.7%	-5.0%
80% Reduction Tax Case	3.1%	4.8%	9.4%	-18%	-6.5%
Refined Petroleum Products					
$20 Tax Case	-0.6%	-2.5%	-6.4%	-9.0%	-11%
80% Reduction Tax Case	-0.6%	-4.4%	-9.9%	-22%	-63%

Figure 20 shows the estimated changes in output for the non-energy side of the economy in the two carbon cases. The measure of sectoral output can be confusing because it is stated in dollar values. If the cost of a product or services increases due to the cost of reducing carbon emissions, the value of output might increase, even if total quantity of physical output has fallen. Although this price-increasing effect is implicit in the model's output projections, the percentage decline in physical output is generally larger, with negative percentage declines in the dollar value of output being projected. The energy-intensive sector is hit relatively hard because it relies on fossil fuels and has higher carbon intensity than most other sectors.

Figure 20: Non-Energy Sector Output (Percentage Change from Baseline)

	2013	2023	2033	2043	2053
Agriculture					
$20 Tax Case	-0.6%	-1.4%	-1.3%	-1.6%	-1.8%
80% Reduction Tax Case	-0.3%	-1.1%	-1.8%	-5.8%	-9.7%
Commercial/Services					
$20 Tax Case	-0.1%	-0.4%	-0.4%	-0.5%	-0.5%
80% Reduction Tax Case	-0.1%	-0.5%	-0.7%	-1.6%	-2.7%
Transportation Services (excluding Personal Transportation)					
$20 Tax Case	-0.3%	-0.8%	-0.8%	-1.0%	-1.1%
80% Reduction Tax Case	-0.2%	-0.9%	-1.4%	-3.6%	-5.9%
Energy-Intensive Manufacturing					
$20 Tax Case	-0.4%	-2.2%	-2.2%	-2.6%	-2.7%
80% Reduction Tax Case	-0.2%	-2.2%	-3.4%	-8.4%	-15%
Non-Energy-Intensive Manufacturing					
$20 Tax Case	-0.7%	-1.0%	-0.9%	-1.1%	-1.3%
80% Reduction Tax Case	-0.3%	-0.5%	-1.0%	-4.6%	-7.7%

5. Economic Welfare

Economic welfare is a concept used by economists that relates to the overall utility that individuals experience from the economy. In $N_{ew}ERA$, welfare is measured by the sum of the values of household consumption and leisure.

Figure 21 provides information on the effects of the two carbon tax cases on changes in the welfare of U.S. households, expressed as percentage changes relative to the Baseline, with information on regional impacts as well as national impacts. The $20 Tax Case leads to an average U.S. welfare loss over the entire modeling horizon of 0.17% relative to the Baseline, and the 80% Reduction Tax Case produces an average U.S. welfare loss of 0.59%. The regional impacts vary considerably, largely reflecting the wide regional variations in carbon intensity, as shown in Figure 10. Higher carbon intensity leads to larger fossil fuel cost increases, which result in higher price impacts and larger reductions in household consumption.

Figure 21: Regional Percentage Changes in Economic Welfare (2013-2053)

Region	$20 Tax Case	80% Reduction Tax Case
Arizona and Mountain States	-0.57%	-1.29%
California	0.06%	-0.19%
Florida	-0.07%	-0.35%
Mid-Atlantic	-0.12%	-0.45%
Mid-America	-0.32%	-0.89%
Mississippi Valley	-0.23%	-0.67%
New York/New England	0.14%	-0.03%
Pacific Northwest	-0.09%	-0.55%
Southeast	-0.29%	-0.76%
Texas, Oklahoma, Louisiana	-0.23%	-0.94%
Upper Midwest	-0.58%	-1.16%
U.S.	**-0.17%**	**-0.59%**

B. Emissions and Energy Market Impacts

1. Carbon Emissions within U.S. Borders

Figure 22 shows baseline carbon emissions (in millions of metric tons of CO_2), along with emissions for the two carbon tax cases and percentage reductions in emissions relative to the Baseline and the emission level in 2005 (5,988 million metric tons). These results reflect only emissions from activities that occur physically within U.S. borders.[25] Note that in the 80% Reduction Tax Case, the U.S. does not fully achieve an 80% reduction (relative to 2005 levels) by 2053, which reflects just how costly such an outcome would be.

Figure 22: Carbon Emissions (Million Metric Tons of CO_2)

	2013	2023	2033	2043	2053
Baseline					
CO_2 Emissions	5,450	5,530	5,650	5,790	5,890
$20 Tax					
CO_2 Emissions	5,210	4,670	4,590	4,640	4,110
% Reduction from Baseline	*4%*	*16%*	*19%*	*20%*	*30%*
% Reduction from 2005	*13%*	*22%*	*23%*	*23%*	*31%*
80% Reduction					
CO_2 Emissions	5,210	4,400	3,610	2,590	1,760
% Reduction from Baseline	*4%*	*20%*	*36%*	*55%*	*70%*
% Reduction from 2005	*13%*	*27%*	*40%*	*57%*	*71%*

[25] Possible leakage of some of the decreases in U.S. emissions to other countries is not quantified in this analysis.

2. Fossil Fuel Markets

The imposition of a carbon tax leads to higher costs for consuming fossil fuels and reduced consumption of fossil fuels in the long term. In the near term, fuel switching (particularly in the electricity sector) from coal to natural gas, which has a lower carbon content, increases natural gas consumption, but in the long term, natural gas consumption also declines as the carbon taxes increase. Figure 23 shows the fuel consumption for coal, natural gas, and gasoline for the Baseline and the two carbon tax cases, stated in physical units.

Figure 23: Fossil Fuel Consumption (in Quadrillion Btu or Billions of Gallons)

	2013	**2023**	**2033**	**2043**	**2053**
Coal (Quadrillion Btu)					
Baseline	20	21	22	23	24
$20 Tax Case	17	13	14	16	13
80% Reduction Tax Case	17	11	5	3	5
Natural Gas (Quadrillion Btu)					
Baseline	24	25	26	28	30
$20 Tax Case	25	25	25	26	27
80% Reduction Tax Case	25	26	27	21	21
Gasoline (Billions of Gallons)					
Baseline	130	118	113	111	108
$20 Tax Case	130	115	109	106	101
80% Reduction Tax Case	130	114	106	91	70

The significant declines in coal consumption reflect that coal has the highest carbon content among the fossil fuels. With the majority of coal consumption occurring within the electricity sector, it also suffers from having some of the least costly fuel-switching opportunities (changes in dispatch from existing generating capacity), which allows for the near-term reductions. In the 80% Reduction Tax Case, all coal consumption in the later years is from outside of the electricity sector.

Natural gas consumption increases immediately in both tax cases due to fuel switching from coal to natural gas in the electricity sector. In the later years of the 80% Reduction Tax Case, natural gas becomes too costly to use in large quantities in the electricity sector and is replaced by low- or zero-emitting technologies such as renewables and nuclear. In the carbon tax cases, natural gas demand increases somewhat between 2043 and 2053 because of the deployment of CNG vehicles.

Demand for gasoline decreases over time in the Baseline because of increasing fuel economy standards. The carbon tax provides an incentive to adopt more fuel-efficient vehicles and consumers drive fewer miles due to the higher price of gasoline, which together combine to lower gasoline demand over time in both carbon tax cases.

Figure 24 shows the impacts on the prices of fossil fuels. The upper portion of the figure shows the percentage change in the resource prices for coal and natural gas (i.e., these are the costs of physically producing the commodities, before including the cost of the carbon tax). The lower portion of the figure then shows the total cost of using those fuels, which includes the carbon tax adder that will have to be paid in order to actually use those fuels (whether paid directly by the fuel consumer, or as a cost passed through by the fuel producer who has already paid the tax "upstream" of the point of use).

One can see from the upper portion of the figure that the resource cost declines when demand declines. For example, the carbon tax policy causes coal demand to decline the most (see Figure 23), and the cost of producing coal to meet that lower demand falls. However, that reduction in demand only occurs because the cost of consuming the coal is driven upward by the carbon tax adder. This can be seen in the lower portion of the figure, which shows that the full cost of using coal, when accounting for the carbon adder as well as the resource cost, increases significantly. Coal incurs the largest full cost increase because it has the highest carbon content per unit of energy content, and so its carbon tax adder is the largest among all the fuels.

Figure 24: Fuel Price Impacts (Percentage Change from Baseline)

	2013	**2023**	**2033**	**2043**	**2053**
Excluding Carbon Tax					
Minemouth Coal Prices					
$20 Tax Case	-6.4%	-13%	-14%	-15%	-9.4%
80% Reduction Tax Case	-9.0%	-11%	-31%	-22%	-15%
Wellhead Natural Gas Prices					
$20 Tax Case	16%	0.3%	0.7%	-2.0%	-4.3%
80% Reduction Tax Case	16%	4.8%	6.8%	-15%	-8.6%
Including Carbon Tax					
Minemouth Coal Prices					
$20 Tax Case	110%	143%	191%	281%	503%
80% Reduction Tax Case	107%	199%	390%	1,574%	5,324%
Wellhead Natural Gas Prices					
$20 Tax Case	44%	33%	39%	39%	44%
80% Reduction Tax Case	44%	49%	85%	206%	497%
Gasoline					
$20 Tax Case	6.0%	7.4%	9.9%	12%	17%
80% Reduction Tax Case	6.5%	9.0%	17%	60%	164%

3. Electricity Sector

The electricity sector has the highest carbon intensity and thus the impacts of the carbon tax are large. Figure 25 shows the residential delivered electricity prices in the Baseline and the two tax cases. In the Baseline, residential electricity prices are projected to increase primarily due to increasing fuel prices over time. The addition of a carbon tax in 2013 is an immediate shock to prices, which is tempered slightly by fuel switching from coal-fired generation to natural gas-fired generation. As the carbon tax price increases, so do the impacts on price, although in the later years of the 80% Reduction Tax Case the electricity sector is nearly completely de-carbonized, so the higher carbon prices have a more limited percentage impact.

Figure 25: Residential Delivered Electricity Prices (2012¢/kWh)

	2013	**2023**	**2033**	**2043**	**2053**
Baseline	12.0¢	13.7¢	14.3¢	16.0¢	17.1¢
$20 Tax Case	13.4¢	15.4¢	16.7¢	19.3¢	20.5¢
Percentage Change from Baseline	*12%*	*12%*	*16%*	*21%*	*20%*
80% Reduction Tax Case	13.5¢	16.2¢	18.6¢	25.9¢	24.3¢
Percentage Change from Baseline	*13%*	*18%*	*30%*	*61%*	*42%*

Figure 26 shows projected physical impacts on the electricity sector in terms of coal electricity unit retirements and overall electricity demand. As expected, the imposition of a carbon tax increases the quantity of coal unit retirements, with higher tax rates leading to a greater level of retirements. Even the $20 Tax Case is projected to cause three times the amount of coal retirements in the near term compared to that projected for the Baseline without any carbon tax. The near-term retirements of the coal units are motivated by the anticipated higher carbon taxes in later years (which make further near-term capital investments to keep such plants operational uneconomical). However, the extent of the coal unit retirement sensitivity is exacerbated by relatively low forecasted prices for natural gas. Under the $20 Tax Case, electricity demand declines about 11% below the Baseline level in 2033 and about 12% in 2053; the 80% Reduction Tax Case causes electricity demand to drop by about 17% in 2033 and more than 25% afterward relative to the Baseline.

Figure 26: Electricity Sector Impacts of Carbon Tax Cases

	2013	2023	2033	2043	2053
Baseline					
Coal Retirements (GW)	4	36	37	39	39
U.S. Electricity Demand (TWh)	3,990	4,280	4,640	4,990	5,380
$20 Tax Case					
Coal Retirements (GW)	5	108	112	119	160
U.S. Electricity Demand (TWh)	3,890	3,960	4,150	4,370	4,740
% Change (Relative to Baseline)	*-2.4%*	*-7.7%*	*-11%*	*-12%*	*-12%*
80% Reduction Tax Case					
Coal Retirements (GW)	5	141	213	295	295
U.S. Electricity Demand (TWh)	3,890	3,830	3,840	3,590	4,020
% Change (Relative to Baseline)	*-2.4%*	*-11%*	*-17%*	*-28%*	*-25%*

4. Alternate Transportation Fuels

To lower carbon taxes in the transportation sector consumers must either consume less transportation fuel or use transportation fuels with lower carbon contents than traditional gasoline and diesel fuel. With respect to fuels, both of the tax cases add significant quantities of advanced biofuels with lower carbon contents than traditional transportation fuels. (The available advanced biofuels are described in Section II.C.1 and in Appendix B.) By 2053, advanced biofuels production doubles from that in the Baseline in the $20 Tax Case. The 80% Reduction Tax Case's advanced biofuels production is more than eight time higher than the Baseline by 2053.

Figure 27: Advanced Biofuels Production (Quadrillion Btu)

	2013	2023	2033	2043	2053
Baseline	0.0	0.0	0.0	1.0	3.1
$20 Tax Case	0.0	0.0	2.1	4.2	6.4
80% Reduction Tax Case	0.0	1.1	3.2	5.3	25.9

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APPENDIX A. NEWERA MODEL

NERA developed the NewERA model to forecast the impact of policy, regulatory, and economic factors on the energy sectors and the economy. When evaluating policies that have significant impacts on the entire economy, one needs to use a model that captures the effects as they ripple through all sectors of the economy and the associated feedback effects. The NewERA model combines a macroeconomic model with all sectors of the economy (except for the electricity sector) with a detailed electricity sector model. This combination allows for a complete understanding of the economic impacts of different policies on all sectors of the economy.

The macroeconomic model incorporates production and consumption of all goods and services in the economy. The amount of labor, capital, energy, and materials used to produce electricity and coal used in the electricity sector are taken from the electricity sector model. Policy consequences are transmitted throughout the economy as sectors respond until the economy reaches equilibrium. The production and consumption functions employed in the model enable gradual substitution of inputs in response to relative price changes, thus avoiding all-or-nothing solutions.

The main benefit of the integrated framework is that the electricity sector can be modeled in great detail yet through integration the model captures the interactions and feedbacks between all sectors of the economy. Electricity technologies can be well represented according to engineering specifications. The integrated modeling approach also provides consistent price responses since all sectors of the economy are modeled. In addition, under this framework, we are able to model electricity demand response.

There are great uncertainties about how the U.S. natural gas market will evolve, and the NewERA model is designed explicitly to address the key factors affecting future natural gas supply and prices. One of the major uncertainties is the availability of shale gas in the United States. To account for this uncertainty and the subsequent effect it could have on the domestic and international markets, the NewERA model includes resource supply curves for U.S. natural gas that can be altered for sensitivity analysis. The model also accounts for foreign imports and U.S. exports of natural gas, by using a supply (demand) curve for U.S. imports (exports) that represents how the global LNG market price would react to changes in U.S. imports or exports.

The electricity sector model is a detailed model of the electricity and coal sectors. Each of the more than 17,000 electricity generating units in the United States is represented in the model. The model minimizes costs while meeting all specified constraints, such as demand, peak demand, emissions limits, and transmission limits. The model determines investments to undertake and unit dispatch. Because the NewERA model is an integrated model of the entire U.S. economy, electricity demand can respond to changes in prices and supplies. The steam coal sector is represented within the NewERA model by a series of coal supply curves and a coal transportation matrix. The NewERA model represents the domestic and international crude oil and refined petroleum markets.

NewERA model outputs include demand and supply of all goods and services, prices of all commodities, and terms of trade effects (including changes in imports and exports). The model outputs also include GRP, consumption, investment, disposable income, and changes in "job-equivalents" based on labor wage income.

Impacts on workers are often considered an important output of policy evaluations. Impacts on workers are complicated to estimate and to explain because they can include several different impacts, including involuntary unemployment, reductions in wage rates for those who continue to work, and voluntary reductions in hours worked due to lower wage rates. No model addresses all of these potential impacts. The NewERA model is a long-run equilibrium model based upon full employment, and thus its results relate to the longer-term effects on labor income and voluntary reductions in hours worked rather than involuntary unemployment impacts. It addresses long-run employment impacts, all of which are based on estimates of changes in labor income, also called the "wage bill" or "payments to labor." Labor income impacts consist of two effects: (1) changes in real wage per hour worked; and (2) changes in labor market participation (hours worked) in response to changed real wage rates. The labor income change can also be expressed on a per-household basis, which represents one of the key components of disposal income per household. (The other key components of disposable income are returns on investments or "payments to capital," and income from ownership of natural resources). The labor income change can also be stated in terms of job-equivalents, by dividing the labor income change by the annual income from the average job. A loss of one job-equivalent does not necessarily mean one less employed person—it may be manifested as a combination of fewer people working and less income per person who is working. However, this measure allows us to express employment-related impacts in terms of an equivalent number of employees earning the average prevailing wage.

A. Overview

NERA's NewERA modeling system is an integrated energy and economic model that includes a bottom-up representation of the electricity sector, including all of the unit-level details that are required to accurately evaluate changes in the electricity sector. NewERA integrates the electricity sector model with a macroeconomic model that includes all other sectors of the economy (except for the electricity sector) using a top-down representation. The model produces integrated forecasts for future years; the modeling for this study was for the period from 2013 to 2053 with modeling inputs and results for every fifth year in that period. The model produces a standard set of reports that includes the following information.

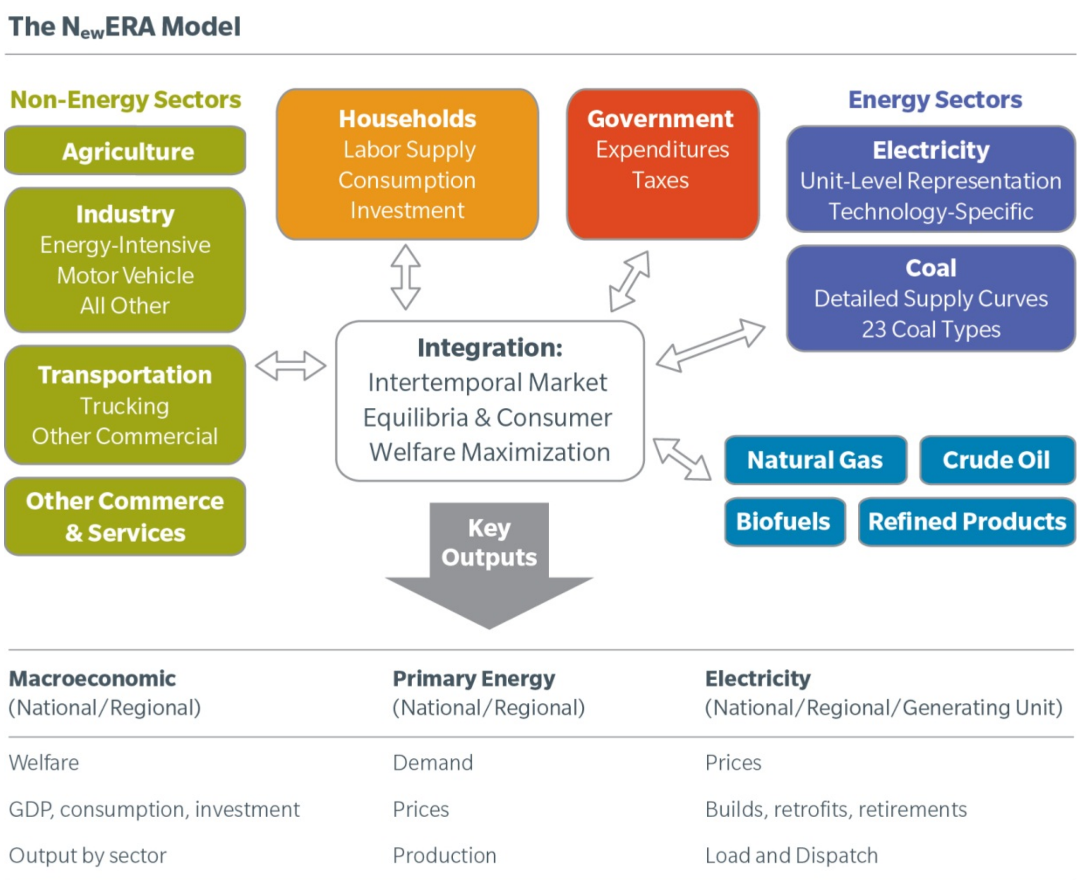
- *Unit-level investments in the electricity sector* – retrofits in response to environmental policies, new builds (full range of new generation technologies represented), retirements based on economics.
- *Prices* – wholesale electricity prices for each of 32 U.S. regions, capacity prices for each U.S. region, delivered electricity prices by sector for each of 11 macroeconomic regions in NewERA, Henry Hub natural gas prices and delivered natural gas prices to the

electricity sector for each U.S. region, minemouth coal prices for 24 different types of coal, delivered coal prices by coal unit, refined oil product prices (gasoline and diesel fuel), renewable energy credit (REC) prices for each state/regional renewable portfolio standard (RPS), and emissions prices for all regional and national programs with tradable credits.

- *Macroeconomic results* – GRP for each macroeconomic region and gross state product (GSP) for each state, economic welfare, changes in disposable income, and changes in labor income and real wage rates (used to estimate labor market changes in terms of an equivalent number of jobs).

Figure 28 provides a simplified representation of the key elements of the N$_{ew}$ERA modeling system.

Figure 28: N$_{ew}$ERA Modeling System Representation



B. Electricity Sector Model

The electricity sector model that is part of the N$_{ew}$ERA modeling system is a bottom-up model of the electricity and coal sectors. The model is fully dynamic and includes perfect foresight (under the assumption that future conditions are known). Thus, all decisions within the model are based on minimizing the present value of costs over the entire time horizon of the model while meeting all specified constraints, including demand, peak demand, emissions limits, transmission limits, RPS regulations, fuel availability and costs, and new build limits. The model set-up is intended to mimic (as much as is possible within a model) the approach that electricity sector investors use to make decisions. In determining the least-cost method of satisfying all these constraints, the model endogenously decides:

- What investments to undertake (*e.g.*, addition of retrofits, build new capacity, repower unit, add fuel switching capacity, or retire units);
- How to operate each modeled unit (*e.g.*, when and how much to operate units, which fuels to burn) and what is the optimal generation mix; and
- How demand will respond. The model thus assesses the trade-offs between the amount of demand-side management (DSM) to undertake and the level of electricity usage.

Each unit in the model has certain actions that it can undertake. For example, all units can retire, and many can undergo retrofits. Any publicly-announced actions, such as planned retirements, planned retrofits (for existing units), or new units under construction can be specified. Coal units have more potential actions than other types of units. These include retrofits to reduce emissions of SO_2, NO_X, mercury, and CO_2. The costs, timing, and necessity of retrofits may be specified as scenario inputs or left for the model to endogenously select. Coal units can also switch the type of coal that they burn (with practical unit-specific limitations). Finally, coal units may retire if none of the above actions will allow them to remain profitable, after accounting for their revenues from generation and capacity services.

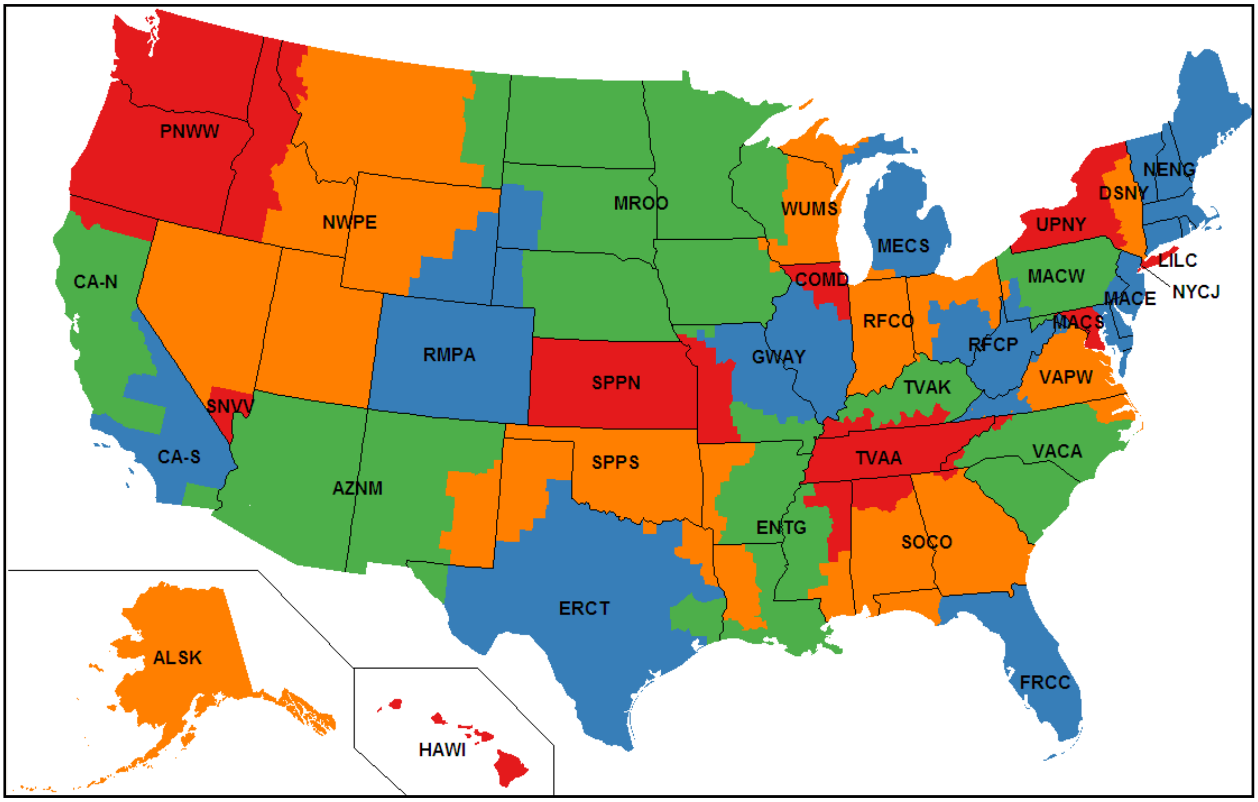
Most of the coal units' actions would be in response to environmental limits that can be added to the model. These include emission caps (for SO_2, NO_X, mercury, and CO_2) that can be applied at the national, regional, state or unit level. We can also specify allowance prices for emissions, emission rates (especially for toxics such as mercury) or heat rate levels that must be met.

Just as with investment decisions, the operation of each unit in a given year depends on the policies in place (*e.g.*, unit-level standards), electricity demand, and operating costs, especially energy prices. The model accounts for all these conditions in deciding when and how much to operate each unit. The model also considers system-wide operational issues such as environmental regulations, limits on the share of generation from intermittent resources, transmission limits, and operational reserve margin requirements in addition to annual reserve margin constraints.

To meet increasing electricity demand and reserve margin requirements over time, the electricity sector must build new generating capacity. Future environmental regulations and forecasted energy prices influence which technologies to build and where. For example, if a national RPS policy is to take effect, some share of new generating capacity will need to come from renewable power. On the other hand, if there is a policy to address emissions, it might elicit a response to retrofit existing fossil-fired units with pollution control technology or enhance existing coal-fired units to burn different types of coals, biomass, or natural gas. Policies calling for improved heat rates may lead to capital expenditure spent on repowering existing units. All of these policies will also likely affect retirement decisions. The N_{ew}ERA electricity sector model endogenously captures all of these different types of decisions.

The model contains 32 U.S. electricity regions (and six Canadian electricity regions). Figure 29 shows the U.S. electricity regions.

Figure 29: N_{ew}ERA Electricity Sector Model – U.S. Regions



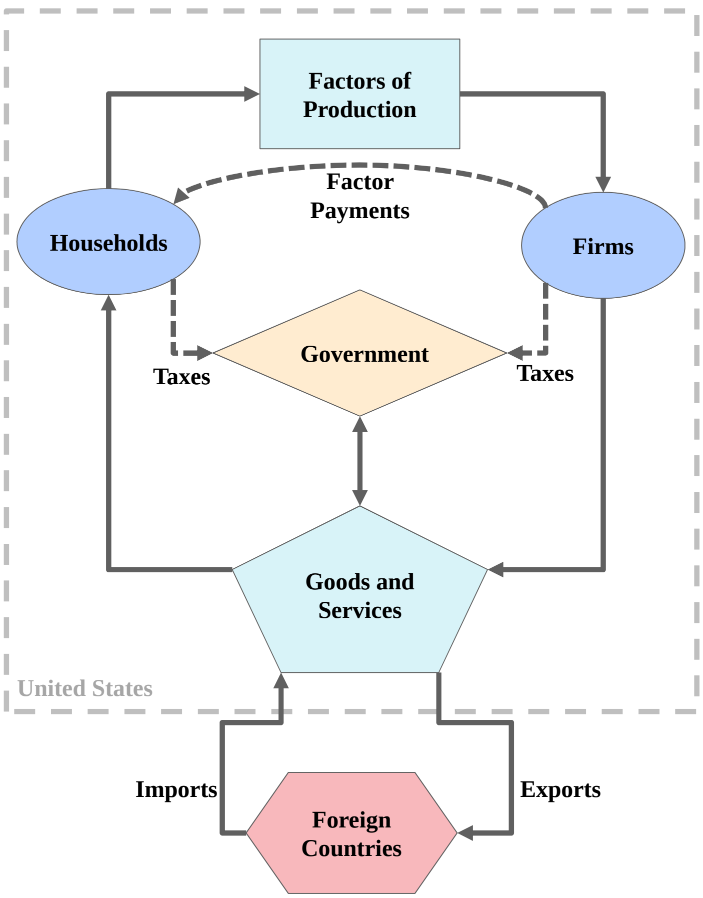
C. Macroeconomic Model

1. Overview

The N_{ew}ERA macroeconomic model is a forward-looking dynamic CGE model of the United States. The model simulates all economic interactions in the U.S. economy, including those among industry, households, and the government. Additional background information on CGE models can be found in Burfisher (2011).

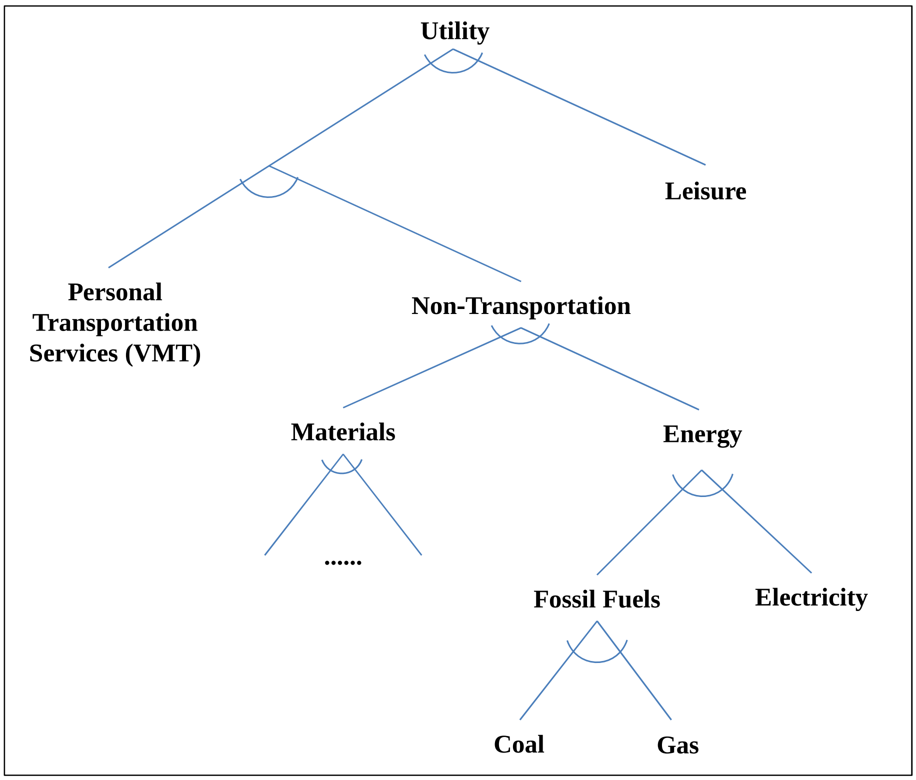
The N_{ew}ERA CGE framework uses the standard theoretical macroeconomic structure to capture the flow of goods and factors of production within the economy. A simplified version of these interdependent macroeconomic flows is shown in Figure 30. The model implicitly assumes "general equilibrium," which implies that all sectors in the economy are in balance and all economic flows are endogenously accounted for within the model. In this model, households supply factors of production, including labor and capital, to firms. Firms provide households with payments for the factors of production in return. Firm output is produced from a combination of productive factors and intermediate inputs of goods and services supplied by other firms. Individual firm final output can be consumed within the United States or exported. The model also accounts for imports into the United States. In addition to consuming goods and services, households can accumulate savings, which they provide to firms for investments in new capital. Government receives taxes from both households and firms, contributes to the production of goods and services, and also purchases goods and services. Although the model assumes equilibrium, a region in the model can run deficits or surpluses in current accounts and capital accounts. In aggregate, all markets clear, meaning that the sum of regional commodities and factors of production must equal their demands, and the income of each household must equal its factor endowments plus any net transfers received.

Figure 30: Interdependent Economic Flows in N$_{ew}$ERA's Macroeconomic Model



The model uses the standard CGE framework developed by Arrow and Debreu (1954). Behavior of households is represented by a nested Constant Elasticity of Substitution (CES) utility function. The model assumes that households seek to maximize their overall welfare, or utility, across time periods. Households have utility functions that reflect trade-offs between leisure (which reduces the amount of time available for earning income) and an aggregate consumption of goods and services. Households maximize their utility over all time periods subject to an intertemporal budget constraint based on their income from supplying labor, capital, and natural resource to firms. In each time period, household income is used to consume goods and services or to fund investment. Within consumption, households substitute between energy (including electricity, coal, natural gas, and petroleum), personal transportation, and goods and services based on the relative price of these inputs. Figure 31 illustrates the utility function of the households.

Figure 31: Household Consumption Structure in N_{ew}ERA's Macroeconomic Model



On the production side, Figure 32 shows the production structure of the commercial transportation and the trucking sector. Production structure for the rest of the industries is shown in Figure 33. The model assumes all industries maximize profits subject to technological constraints. The inputs to production are energy (including the same four types noted above for household consumption), capital, and labor. Production also uses inputs from intermediate products provided by other firms. The N_{ew}ERA model allows producers to change the technology and the energy source they use to manufacture goods. If, for example, petroleum prices rise, an industry can shift to a cheaper energy source. It can also choose to use more capital or labor in place of petroleum, increasing energy efficiency and maximizing profits with respect to industry constraints.

Figure 32: Commercial Transportation and Trucking Sector Production Structure in N_{ew}ERA's Macroeconomic Model

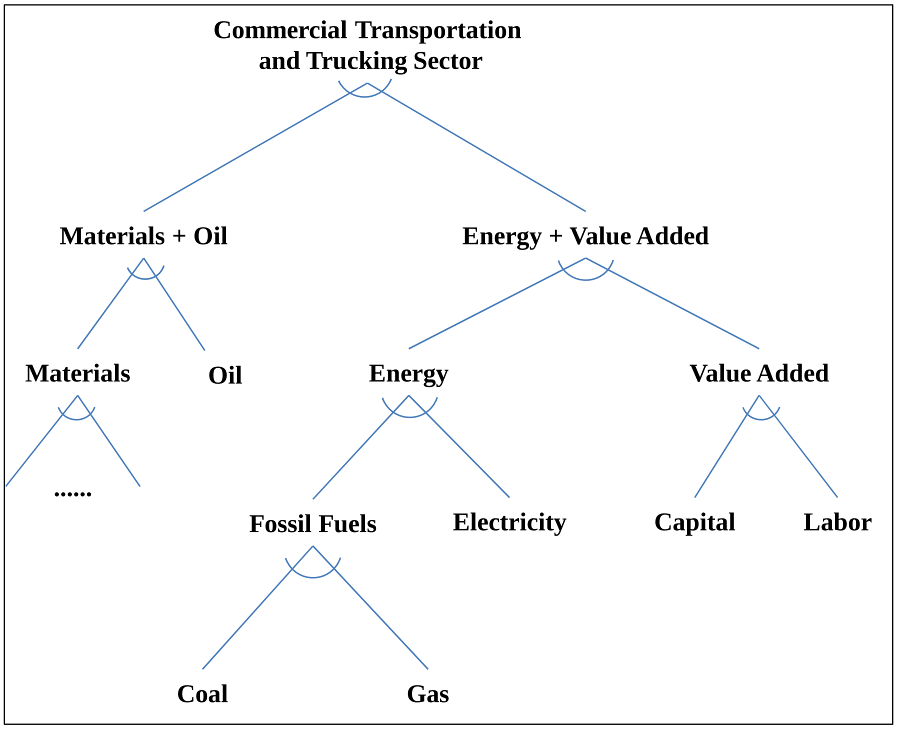
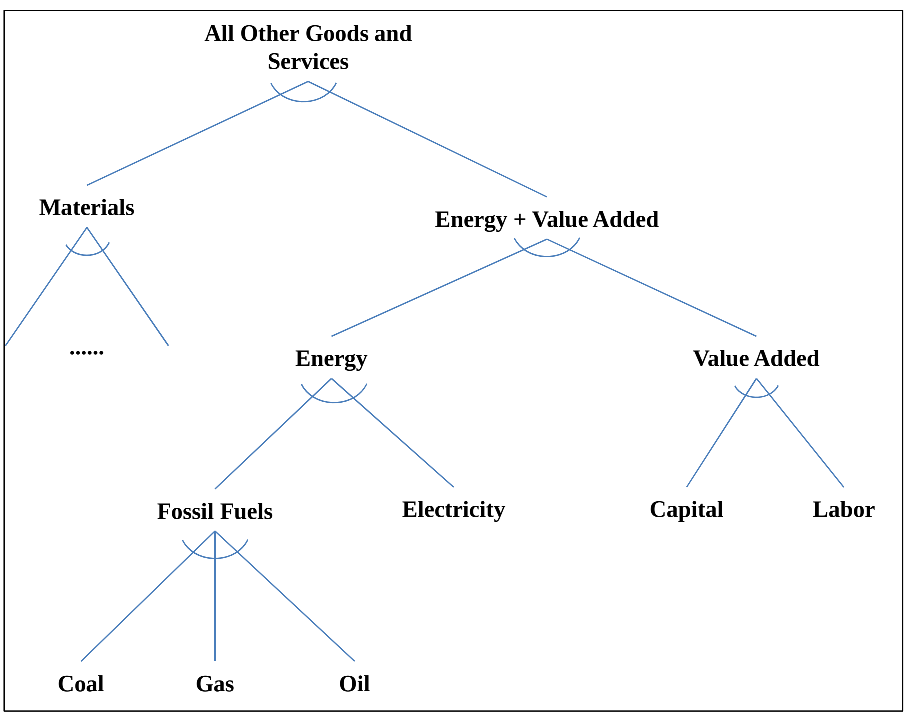


Figure 33: Production Structure for Other Sectors in N_{ew}ERA's Macroeconomic Model



All goods and services, except crude oil, are treated as Armington goods, which assume the domestic and foreign goods are differentiated and thus are imperfect substitutes (Armington 1969). The level of imports depends upon the elasticity of substitution between the imported and domestic goods. The Armington elasticity among imported goods is assumed to be twice as large as the elasticity between the domestic and imported goods, characterizing the greater substitutability among imported goods.

Business investment decisions are informed by future policies and outlook. The forward-looking characteristic of the model enables businesses and consumers to determine the optimal savings and investment levels while anticipating future policies with perfect foresight.

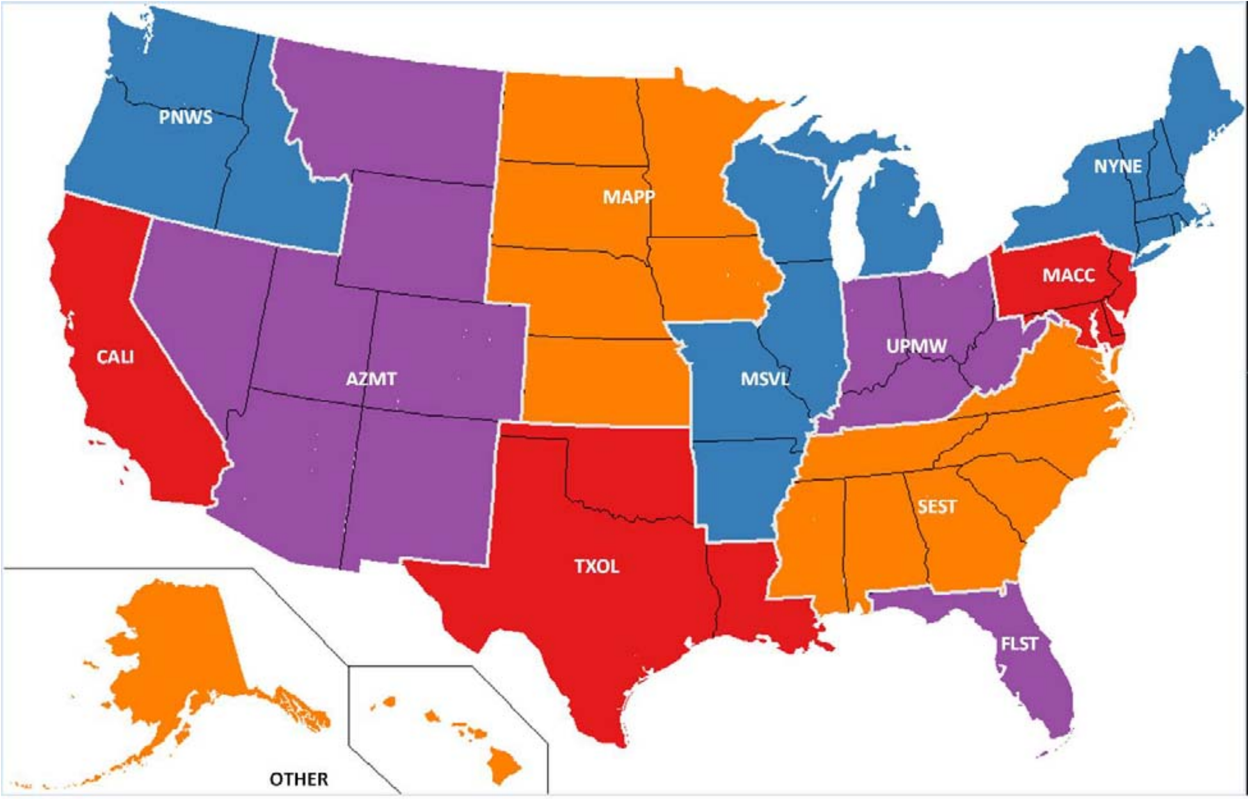
The benchmark year economic interactions are based on the IMPLAN 2008 database, which includes regional detail on economic interactions among 440 different economic sectors. The macroeconomic and energy forecasts that are used to project the benchmark year going forward are calibrated to EIA's AEO 2012.

2. Regional Aggregation

The N_{ew}ERA macroeconomic model typically includes 11 regions: NYNE (New York and New England), MAAC (Mid-Atlantic Coast), UPMW (Upper Midwest), SEST (Southeast), FLST (Florida), MSVL (Mississippi Valley), MAPP (Mid-America), TXOL (Texas, Oklahoma and Louisiana), AZMT (Arizona and Mountain states), CALI (California) and (PNWS) Pacific Northwest. The aggregate model regions are built up from economic data for the 50 U.S. states and the District of Columbia. The 11 standard N_{ew}ERA macroeconomic model regions and the states within each N_{ew}ERA region are shown in Figure 34.

The model's regional representation can also be adjusted to include individual states. This is done when one wishes to evaluate the impacts to a specific state. This is done by creating one additional region, for a total of 12 regions. The state of interest is removed from the region that it is a part of and becomes its own region. Such an approach requires nearly 50 different model runs (California and Florida are already their own region in the standard 11-region model representation) to assess the impacts to each state individually associated with a particular national or regional scale policy analysis.

Figure 34: N_{ew}ERA Macroeconomic Model Regions



3. Sectoral Aggregation

The N_{ew}ERA model includes a standard set of 12 economic sectors: five energy (coal, natural gas, crude oil, electricity, and refined petroleum products) and seven non-energy sectors (services, manufacturing, energy-intensive,[26] agriculture, commercial transportation excluding trucking, trucking, and motor vehicle manufacturing). These sectors are aggregated up from the 440 IMPLAN sectors. The model has the flexibility to represent sectors at different levels of aggregation, when warranted, to better meet the needs of specific analyses.

4. Natural Gas and Oil Markets

The N_{ew}ERA modeling system is designed explicitly to address the key factors affecting future natural gas supply and prices. One of the major uncertainties is the availability of shale gas in the United States. To account for this uncertainty and the subsequent effect it could have on international markets, the N_{ew}ERA modeling system has the ability to represent supply curves for conventional natural gas and shale gas for each region of the model. By including each type of natural gas, it is possible to incorporate expert judgments and sensitivity analyses on a variety of

[26] The energy-intensive sector in the N_{ew}ERA modeling system includes pulp and paper, chemicals, glass, cement, primary metals, and aluminum.

uncertainties, such as the extent of shale gas reserves, the cost of shale gas production, and the impacts of environmental regulations.

The N_{ew}ERA model represents the domestic and international crude oil and refined petroleum markets. The international markets are represented by flat supply curves with exogenously specified prices. Because crude oil is treated as a homogeneous good, the international price for crude oil sets the U.S. price for crude oil.

Consumption of electricity as a transportation fuel could also affect the natural gas market. Along with alternative transportation fuels (including biofuels), the model also includes different vehicle choices that consumers can employ in response to changes in the fuel prices. The model includes different types of Electrified Vehicles (EVs): Plug-in-Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs).[27] In addition, the model accounts for both passenger vehicles and trucks powered by CNG.

5. Macroeconomic Outputs

As with other CGE models, the N_{ew}ERA macroeconomic model outputs include demand and supply of all goods and services, prices of all commodities, and terms of trade effects (including changes in imports and exports). The model outputs also include GRP, consumption, investment, cost of living or burden on consumers, and changes in "job-equivalents" based on changes in labor wage income. All model outputs are calculated by time, sector, and region.

Impacts on workers are often considered an important output of policy evaluations. Impacts on workers are complicated to estimate and to explain because they can include several different impacts, including involuntary unemployment, reductions in wage rates for those who continue to work, and voluntary reductions in hours worked due to lower wage rates. No model addresses all of these potential impacts. The N_{ew}ERA model is a long-run equilibrium model based upon full employment, and thus its results relate to the longer-term effects on labor income and voluntary reductions in hours worked rather than involuntary unemployment impacts. It addresses long-run employment impacts, all of which are based on estimates of changes in labor income, also called the "wage bill" or "payments to labor." Labor income impacts consist of two effects: (1) changes in real wage per hour worked; and (2) changes in labor market participation (hours worked) in response to changed real wage rates. The labor income change can also be expressed on a per-household basis, which represents one of the key components of disposal income per household. (The other key components of disposable income are returns on investments or "payments to capital," and income from ownership of natural resources). The labor income change can also be stated in terms of job-equivalents, by dividing the labor income change by the annual income from the average job. A loss of one job-equivalent does not

[27] EVs were not included in this analysis due to time constraints. However, previous experience with modeling EVs suggests they would not become economical except in the higher carbon tax case, and only in the later parts of the analysis horizon.

necessarily mean one less employed person—it may be manifested as a combination of fewer people working and less income per person who is working. However, this measure allows us to express employment-related impacts in terms of an equivalent number of employees earning the average prevailing wage.

D. Integrated N_{ew}ERA Model

The N_{ew}ERA modeling framework fully integrates the macroeconomic model and the electricity sector model so that the final solution is a consistent equilibrium for both models and thus for the entire U.S. economy.

To analyze any policy scenario, the system first solves for a consistent baseline solution; it then iterates between the two models to find the equilibrium solution for the scenario of interest. For the Baseline, the electricity sector model is solved first under initial economic assumptions and forecasts for electricity demand and energy prices. The equilibrium solution provides the baseline electricity prices, demand, and supply by region as well as the consumption of inputs—capital, labor, energy, and materials—by the electricity sector. These solution values are passed to the macroeconomic model.

Using these outputs from the electricity sector model, the macroeconomic model solves the Baseline while constraining the electricity sector to replicate the solution from the electricity sector model and imposing the same energy price forecasts as those used to solve the electricity sector Baseline. In addition to the energy price forecasts, the macroeconomic model's non-electric energy sectors are calibrated to the desired exogenous forecast (*e.g.*, EIA's latest AEO forecast) for energy consumption, energy production, and macroeconomic growth. The macroeconomic model solves for equilibrium prices and quantities in all markets subject to meeting these exogenous forecasts.

After solving the Baseline, the integrated N_{ew}ERA modeling system solves for the scenario. First the electricity sector model reads in the scenario definition. The electricity sector model then solves for the equilibrium level of electricity demand, electricity supply, and inputs used by the electricity sector (*i.e.*, capital, labor, energy, emission permits). The electricity sector model passes these equilibrium solution quantities to the macroeconomic model, which solves for the equilibrium prices and quantities in all markets. The macroeconomic model then passes to the electricity sector model the following (solved for equilibrium prices):

- Electricity prices by region;
- Prices of non-coal fuels used by the electricity sector (*e.g.*, natural gas, oil, and biofuels); and
- Prices of any permits that are tradable between the non-electricity and electricity sectors (*e.g.*, carbon permits under a nationwide greenhouse gas cap-and-trade program).

The electricity sector model then solves for the new electricity sector equilibrium, taking the prices from the macroeconomic model as exogenous inputs. The models iterate—prices being sent from the macroeconomic model to the electricity sector model and quantities being sent from the electricity sector model to the macroeconomic model—until the prices and quantities in the two models differ by less than a fraction of a percent.

This decomposition algorithm allows the N_{ew}ERA model to retain the information in the detailed electricity model, while at the same time accounting for interactions with the rest of the economy. The detailed information on the electricity sector enables the model to represent regulatory policies that are imposed on the electricity sector in terms of their impacts at a unit level.

E. References to the Appendix

Armington, P. 1969. "A Theory of Demand for Products Distinguished by Place of Production." *International Monetary Fund Staff Papers*, XVI: 159-78.

Arrow, K.J., and G. Debreu. 1954. "Existence of Equilibrium for a Competitive Economy." *Econometrica* 22:265-290.

Burfisher, M.E. 2011. *Introduction to Computable General Equilibrium Models*. New York: Cambridge University Press.

APPENDIX B. MODELING ASSUMPTIONS

This appendix includes additional details on the Baseline information used in this study for Federal fiscal information and energy information.

A. Baseline Federal Fiscal Information

Figure 35 provides the assumptions about the Baseline's debt level and the Federal government expenditures. As noted in the main body of the report, this Federal debt has been constructed using tax rate and Federal spending assumptions so that it remains at or below GDP in all years through 2053. The Federal government expenditures were set so that, in combination with the Federal tax rates described below, the debt-to-GDP ratio in the Baseline never exceeds 1.0.

Figure 35: Baseline Federal Debt and Federal Government Expenditures (Billions)

	2013	2023	2033	2043	2053
Federal Debt	$12,280	$19,210	$24,010	$30,320	$38,130
Federal Government Expenditures	$3,420	$3,740	$4,150	$4,190	$3,380

As noted in the main body of the report, the Federal tax rates are initially set at 2012 levels, and remain there through 2022. For that initial period, the tax rates for Federal personal capital and labor income are based on those in the National Bureau of Economic Research's (NBER's) TAXSIM model.[28] The Federal corporate income tax rates are from the Tax Foundation.[29] The PIT and corporate income tax rates are represented by a combination of (1) weighted averages of their marginal rates (taking into account that there are multiple marginal rates across income classes), and (2) a lump-sum transfer that is calculated to ensure that total tax revenues are consistent with the average tax rate actually paid after deductions, *etc*. These rates vary somewhat from state to state, as estimated by the NBER and Tax Foundation, due to differences in state income distributions. For 2013-2022, the Baseline average marginal Federal PIT rate is 25% on labor earnings and 12% to 15% (depending on the state) on capital earnings. The Baseline average marginal corporate income tax rate is 30% to 35%, depending on the state. The model estimates a weighted average of the state-specific levels to obtain the rates it applies in each of the model's multi-state macroeconomic regions. The FICA and HI rates in the initial period of 2013-2022 are set at 12.4% and 2.9%, respectively.[30]

As explained in the main body of the report, the Federal PIT rates are increased in the model year 2023 to the levels that are assumed in the CBO "Extended Baseline Scenario," which are the pre-2001 levels. This is done as one of two steps to hold the Baseline debt at a level that does not exceed GDP in any year (the other step being holding projected government spending to

[28] See http://users.nber.org/~taxsim/ for more information.

[29] See http://taxfoundation.org/ for more information.

[30] See http://www.ssa.gov/oact/progdata/taxRates.html for more information.

the levels shown in Figure 35). To achieve tax revenues equivalent to those of the CBO "Extended Baseline Scenario," baseline Federal PIT rates from 2023 through the end of the model horizon are raised by a factor of about 1.35 from the levels in effect during the model years 2013-2022, and the FICA rate is increased to 14.4%. The corporate income and HI tax rates remain at their initial 2013-2022 rates. (The tax rate increases in the Baseline that occur in 2023 should not be confused with the changes in PIT rates that occur in the carbon tax cases; changes from the Baseline's PIT rates that occur in the carbon tax cases are model results and are reported as percentage changes relative to the baseline rates described here.)

The model also accounts for state personal and corporate income taxes. Like the Federal rates, these are also obtained from NBER's TAXSIM model and the Tax Foundation, respectively. The Baseline rates are the same in all years of the modeled period (they do not change in 2023 as do the Federal rates). The state PIT income tax rates are zero in eight states, and the average marginal rate varies from about 3% to about 8% in the states that do have personal income taxes. The state corporate income tax rates are zero in six states, and the average marginal rate varies from about 3% to about 10% in the states that do have corporate income taxes. As with Federal tax rates, the model estimates a weighted average of state-specific levels to obtain the rates it applies in each of the model's multi-state macroeconomic regions.

B. Baseline Energy Information

Figure 36 reports the prices for natural gas and crude oil that the Baseline is calibrated to. These are national prices, based on AEO 2012. (Coal prices are specific to the type of coal, and are calculated endogenously in the model based on detailed coal supply curves. The results generally match those of AEO 2012.)

Figure 36: Baseline Fuel Prices ($/MMBtu)

	2013	2023	2033	2043	2053
Natural Gas (Wellhead)	$3.78	$4.85	$6.09	$8.42	$10.49
Crude Oil	$90	$112	$125	$149	$165

Figure 37 includes input assumptions for new electricity generating capacity. Capital costs of new generating capacity are based on the assumptions in AEO 2012, including the cost reductions over time (costs remain flat post-2033). The costs of each technology in each electricity region vary from these costs based on regional cost factors. Not included in the figure are costs for geothermal because these are site specific. In 2013, these costs range from $1,756/kilowatt (kW) to $22,350/kW and decline by 10% by 2033.

Figure 37: Electricity Generating Capacity Costs ($/kW)

Generating Technology	2013	2023	2033
Pulverized Coal*	$2,958	$2,840	$2,811
Coal Integrated Gasification Combined Cycle*	$3,347	$3,143	$3,094
Natural Gas Combined Cycle	$1,067	$1,027	$1,017
Natural Gas Combustion Turbine	$745	$704	$695
Onshore Wind	$2,521	$2,501	$2,496
Offshore Wind	$6,180	$4,325	$3,955
Biomass	$3,992	$3,539	$3,434
Solar PV	$4,919	$4,697	$4,427
Coal with CCS	$5,605	$5,109	$4,848
Combined Cycle with CCS	$2,244	$2,043	$1,923
Nuclear	$5,519	$4,834	$4,731

* Neither Pulverized Coal nor Coal Integrated Gasification Combined Cycle are available new options in this analysis as neither technology can currently meet the proposed New Source Performance Standards for Greenhouse Gases for New Electric Generating Units, however, these are the costs assumptions for these technologies that would be assumed if they were available options

Figure 38: Maximum Cumulative New Capacity Allowed (GW)

Generating Technology	2023	2033	2043	2053
Onshore Wind	102	222	342	462
Offshore Wind	14.5	47.5	100.5	173.5
Biomass	34	66	103	149.5
Solar PV	36	76	116	156
Geothermal	27	57	87	117
Coal with CCS	8	40	100	175
Combined Cycle with CCS	8	40	100	175
Nuclear	28	72	126	186

Baseline U.S. electricity demand grows at a 0.75% compound annual growth rate from 2013 through 2053. Different regions exhibit different growth rates.

Figure 39: Baseline Electricity Demand (TWh)

	2013	2023	2033	2043	2053
U.S. Electricity Demand	3,986	4,284	4,637	4,989	5,377

The $N_{ew}ERA$ model includes five alternative fuels that can substitute for gasoline and three that can substitute for petroleum-based diesel.[31] Two of the defining characteristics of these fuels are their cost and emissions relative to their petroleum-based counterpart. Figure 40 reports the cost of alternative fuels relative to their petroleum-based counterpart. The cost for CNG includes the infrastructure costs associated with this fuel in the light duty vehicle (LDV) and commercial trucking markets.

Figure 40: Relative Costs of Alternative Fuels, Relative to Petroleum-Based Fuels

Alternative Fuel	2013	2023	2033	2043	2053
Corn Ethanol	1.6	1.5	1.5	1.5	1.5
Sugar Ethanol	1.8	1.7	1.7	1.7	1.7
Cellulosic Ethanol	2.7	2.4	2.3	2.3	2.3
CNG for LDVs	1.7	1.6	1.4	1.3	1.3
Biomass to Liquids (BTL) Gasoline	2.7	2.4	2.3	2.3	2.3
Soybean Diesel	1.8	1.7	1.7	1.7	1.7
CNG for Trucks	1.4	1.2	1.0	1.0	1.0
BTL Diesel	2.7	2.4	2.3	2.3	2.3

Figure 41 reports the emissions of the alternative fuels relative to their petroleum-based counterpart.

Figure 41: Emission Factors of Alternative Fuels, Relative to Petroleum-Based Fuels

Transportation Fuel	Emission Factor
Gasoline	*1.00*
Corn Ethanol	0.84
Sugar Ethanol	0.67
Cellulosic Ethanol	0.26
BTL Gasoline	0.21
CNG for LDVs	0.71
Diesel	*1.00*
Soybean Diesel	0.83
BTL Diesel	0.21
CNG for Trucks	0.72

[31] Additionally, the model has the ability to include EVs as another personal transportation technology option. This feature was not used in this analysis, so it is not documented here.

C. Other Assumptions

Crude oil is a global commodity with prices driven mostly by supply and demand outside of the United States. However, the 80% Reduction Tax Case is projected to have approximately 50% less consumption of crude oil in 2053 than in the Baseline (the $20 Tax Case only reduces crude consumption by 5% in 2053). Such an extensive change in crude oil demand in the United States is likely to reduce global crude oil prices.

To estimate the extent of the U.S. demand drop on global prices we reviewed results from the MIT Joint Program Report, "The Cost of Climate Policy in the United States."[32] We focused on the 167 billion metric tonnes of carbon dioxide equivalent (bmt) case that had similar reductions in U.S. crude oil consumption and applied the same percentage reductions to the crude oil price in our model (see Figure 42). The lowering of crude oil prices has a slight positive impact on the U.S. economy.

Figure 42: Reductions to Global Crude Oil Prices in 80% Tax Reduction Case

	2013	2023	2033	2043	2053
% Change from Baseline Prices	0%	-4%	-7%	-14%	-16%

[32] The text of the report is available at http://globalchange.mit.edu/pubs/abstract.php?publication_id=1965.

APPENDIX C. THE EFFECTS OF CHANGES IN FEDERAL GOVERNMENT DEBT ON INTEREST RATES

This appendix summarizes the literature on the effects of changes in Federal government debt on the economy, focusing on the potential effects of changes in federal debt on the interest rate on federal debt. We begin with an overview of three alternative conceptual approaches that have been developed to characterize the impacts of changes in Federal debt on the economy. We then summarize the rationales and empirical evidence for these approaches. The next section summarizes the results of the empirical study by Engen and Hubbard (2005) that we use as the basis for our estimate of the effects of changes in Federal debt on the interest rate used to determine government interest payments. The final section provides an overview of other potential effects of the federal debt (beyond changes in interest rates) that have been identified in the economic literature.

A. Overview of Conceptual Approaches for Assessing the Economic Effects of Government Debt

This section provides a framework for considering the linkage between the federal debt and macroeconomic variables. The initial effect of using carbon tax revenues to reduce government debt would be to increase public savings by the amount of the increased federal revenues. In terms of national income accounts, pubic savings are linked to private savings and investment through the following accounting identity:

Public Savings + Private Savings = Domestic Investment + Net Foreign Investment

In the identity above, net foreign investment refers to investment by domestic residents in other countries less domestic investment undertaken by foreign residents.

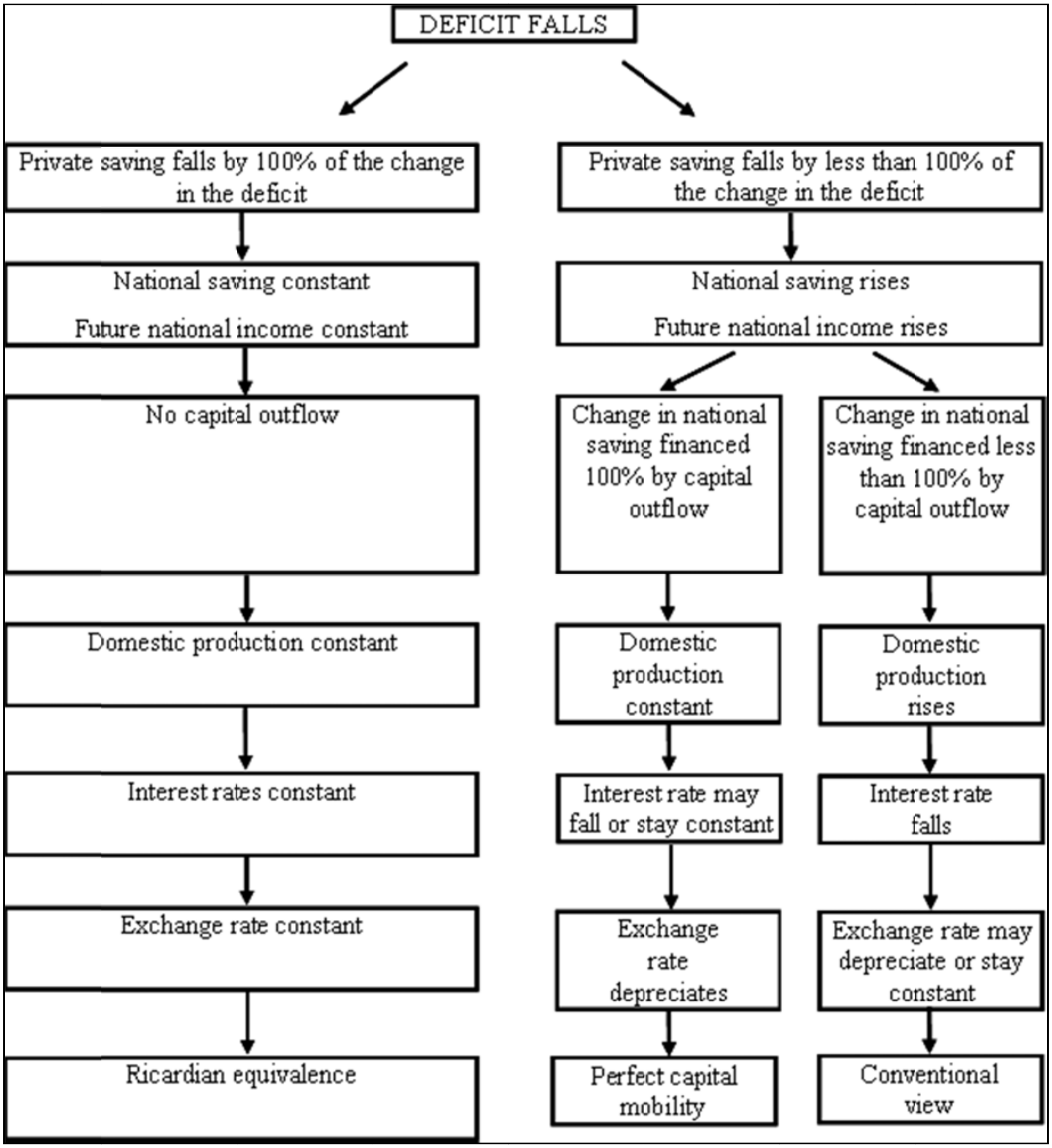
The economic effects of reductions in the Federal debt can be characterized in terms of the potential changes in the other three elements of this accounting identity that could result from the initial increase in public savings.[33] Gale and Orszag (2003) describe three potential outcomes that have been identified in the literature, as summarized below and in Figure 43.

1. **Ricardian equivalence.** This case assumes that an increase in public savings leads to an equal decrease in private savings, leaving total savings (and thus total investment and interest rates) unchanged.
2. **Perfect capital mobility.** This case assumes that an increase in public savings leads to an increase in net foreign investment (*i.e.,* capital inflows from abroad), leaving domestic investment unchanged. This outcome implies that domestic production is unchanged, but the domestic currency will depreciate and interest rates may fall.

[33] This characterization does not include all potential economic effects due to deficit changes. Other potential effects are summarized in the final section of this appendix.

3. **"Conventional view."** This case assumes that an increase in public savings leads to increases in both domestic investment and net foreign investment. This outcome implies that domestic production increases, the domestic currency depreciates and interest rates fall.

Figure 43: Effects of Deficit/Debt Reduction (Adapted from Gale and Orszag, 2003)



B. Theoretical and Empirical Support for Alternative Conceptual Approaches

1. Ricardian Equivalence Approach

One approach identified by Gale and Orszag for assessing the economic effects of government debt is to assume that all households display Ricardian equivalence.

i. The Theory of Equivalence

Budget deficits are reductions in public savings. Households may compensate for an increase in public savings by decreasing their private savings in anticipation of future fiscal policy (*e.g.*, tax decreases).

If all households display Ricardian equivalence (or "Barro-neutrality," which is a related concept), they are sufficiently forward looking that they fully internalize the expected future tax changes implied by changes in the government deficit (Barro (1974)). In other words, private savings would fully adjust to cancel out the changes in public savings, so that no change in interest rates or investment is required for total savings to equal total investment.

As Gale and Orszag note, Ricardian equivalence relies on several strong assumptions, including: 1) fully competitive markets; 2) no borrowing constraints; 3) a transparent tax system and perfect foresight of future fiscal policy; and 4) infinite planning periods of households and governments.

ii. Empirical Evidence on Ricardian Equivalence

Numerous studies of household saving behavior conclude that households respond to budget deficits, but not to the full extent predicted by Barro-neutrality. For example, the CBO (1998) concluded that private saving may offset 20% to 50% of a decline in public savings. Similarly, Elmendorf and Liebman (2000) argue that private saving would offset 25% of an increase in the deficit, and Gale and Potter (2002) estimate that private saving will offset 31% of the decline in public saving caused by the 2001 tax cut.

2. Perfect Capital Mobility Approach

A second approach described by Gale and Orszag (2003) for assessing the impacts of budget deficits assumes that there is an infinitely elastic supply of international capital.

i. The Theory of Perfect International Capital Mobility

The perfect capital mobility approach presumes that net foreign investment adjusts to satisfy the national accounting identity (total savings must equal total investment) and thus domestic investment does not change at all in response to changes in government savings. (Net foreign investment refers to investment by domestic residents in other countries less domestic investment undertaken by foreign residents.)

Under the "perfect capital mobility" approach, budget deficits lead to decreases in net foreign investment, which may lead to decreases in future national income as well, because increased indebtedness to foreigners implies that wealth will flow out of the country in the future (though some portion may eventually re-enter the domestic economy).

In addition, if reduced budget deficits lead to decreased interest rates (either because risk premiums change or because domestic investment is in fact affected by the deficit), domestic investment would become less attractive relative to foreign investment. This would leads to a decrease in the demand for domestic currency, so the domestic currency would depreciate. The depreciation of the domestic currency leads to decreased imports and increased exports, thus decreasing the trade deficit.

ii. Empirical Evidence on Perfect Capital Mobility

As with Ricardian equivalence, the empirical literature does not support the theory of perfect international capital mobility. Net foreign investment does adjust when there are changes in the Federal debt, but it does not fully counteract these changes so that domestic investment would remain unchanged, as the "perfect capital mobility" approach suggests. In other words, the impacts of Federal debt on net foreign investment are not zero but not sufficient to compensate for the full change in public savings when deficits change.

Gale and Orszag (2003) review the literature and estimate that changes in net foreign investment account for roughly between 25% and 40% of changes in national savings. Similarly, Elmendorf and Mankiw (1999) review the literature and estimate that changes in net foreign investment account for about 25% of changes in national savings. They also note that if returns to wealth are the same everywhere, the effects on national income are the same regardless of the extent to which domestic investment and net foreign investment are affected (Elmendorf and Mankiw, (1999)).

3. "Conventional View" of the Effects of Government Debt

The final approach described by Gale and Orszag (2003) for assessing the effects of government debt is referred to as the "conventional view" because it receives the most support in the literature.

i. Economic Theory of the "Conventional View"

The "conventional view" of the effects of government debt is that all three other elements (private savings, domestic investment, and net foreign investment) all adjust with changes in government debt. This view implies that domestic interest rates are affected by changes in the deficit through two potential mechanisms (which are fundamentally equivalent). First, budget deficits represent a decrease in national savings, and firms competing over this smaller pool of funds will need to offer higher rates. Second, budget deficits lead to an increase in the supply of government bonds. To persuade investors to hold more bonds, the government must offer a higher rate (so the price falls). If deficits are decreased, the changes are in the opposite directions, resulting in lower interest rates.

Lower interest rates lead to increased domestic private investment (which is referred to as the "crowding out" effect) and thus a larger long-term capital stock. A change in the capital stock has long-term impacts on the economy, and can lead to changes in technological progress and productivity (see Romer (1987) and DeLong and Summers (1991)).

On the other hand, economists have noted that in certain circumstances deficits can also cause domestic investment to increase when the deficits are used for government infrastructure. Government investment in certain public goods (*e.g.*, highways, airports, sewers) complements private capital and thus "crowds in" private investment (despite any increase in interest rates) because the marginal productivity of private capital rises (see, for example, Aschauer (1989), Eisner (1989), Heng (1997)).

ii. Empirical Evidence on the "Conventional View" of Government Debt

Empirical estimates of the change in domestic private investment due to budget deficits have been inconclusive. These studies range from finding that deficits cause large decreases in investment (*e.g.*, Auerbach and Kotlikoff (1987) find that the decrease in capital stock is roughly the same as any increase in debt, so there is "one-to-one crowding out") to net increases in investment (as noted above, Aschauer (1989), Eisner (1989), and Heng (1997) find that investment is actually "crowded in").

4. Critiques of the Gale and Orszag Conceptual Approaches

The three conceptual approaches described by Gale and Orszag (2003) of the effects of changes in Federal debt on the economy represent a range of potential outcomes that have been identified in the literature. However, it should be noted that other economists reject the Gale and Orszag premise that the major economic effects of deficits stem from the savings/investment accounting identity.

For example, Keynesian economists argue that the primary effects of deficit spending are impacts on real GDP. They argue that the Gale and Orszag approach is valid only in unrealistic models that always assume full employment. Further, investment can rise even if there is a lower investment share of GDP (Galbraith (2005)).

Other economists argue that the treatments of investment and interest rates are incomplete because they do not account for inevitable monetary policy responses to changes in deficits. When deficits occur, monetary authorities (*i.e.*, the central bank) purchase government debt to expand the money supply and keep prices and interest rates relatively constant (Engen and Hubbard (2005)). The recent experience of the United States provides support for this critique. Government debt has increased by an unprecedented amount (over 30% of 2007 levels), but long-term interest rates have actually fallen over this same period to near-record lows.

C. Empirical Estimate of Change in Interest Rates

Many studies that have estimated the relationships between deficits and debt and interest rates. We rely upon a study by Engen and Hubbard (2005) as the basis for the estimate we use of the relationship between federal debt (expressed as a ratio of GDP) and the interest rate.

1. Engen and Hubbard Study

Engen and Hubbard (2005) summarize the literature and provide their own estimates of the effect of changes in government debt on the interest rate. The authors caution that "both economic theory and empirical analysis of the relationship between debt and interest rates have proved inconclusive," and that comparing results across studies is hindered by "different definitions of government debt and interest rates, econometric approaches, sources of data, and rhetoric." The paper also notes that empirical estimates differ markedly based on whether the debt or the deficit is studied (Engen and Hubbard (2005), p. 4).

Engen and Hubbard indicates a small positive relationship between the debt and interest rates that is roughly consistent across its various theoretical and empirical calculations. Specifically, these authors conclude that an increase in federal debt equal to 1% of GDP would increase the long-term interest rate by about 3 basis points.

Recent work by Laubach (2009) has supported the conclusions of Engen and Hubbard. This paper finds a 3 to 4 basis point effect of a 1% increase in the projected debt-to-GDP ratio.

2. Other Empirical Studies and Literature Reviews

Many of the other empirical studies involve estimates of the effects of change in the deficit rather than the debt on interest rates. Barth *et al.* (1991) found that of 42 studies conducted through 1989, 17 found a significant positive effect of deficits on interest rates, 6 found mixed effects, and 19 found predominately insignificant or negative effects. A review by Gale and Orszag (2003) uses the studies collected by Barth *et al.* (1991) and others and finds that when studies without one particular independent variable (a proxy for the expectation of future deficits) are excluded, nearly all the remaining studies find a positive relationship between the deficit and interest rates. From this truncated sample, they postulate an average increase of 40 to 60 basis points in long-term interest rates from a 1% expansion of the *projected* deficit.

Similarly, Gale and Orszag (2004) conduct their own empirical analyses and conclude that "the estimated effect on forward long-term rates from a 1-percent-of-GDP shift in projected primary budget variables ranges between 40 and 67 basis points, depending on the specification and whether the fiscal variable is the primary deficit or revenue and primary outlays separately" (p. 32). They note that the impact on interest rates is notably smaller when the economy is in a recession (p. 30).

Brook (2003) conducted a literature review for the Organisation for Economic Co-operation and Development (OECD) and concludes that "most empirical work conducted in the past ten years estimates the impact on U.S. real long-term interest rates of a sustained 1 percentage point decrease in the U.S. fiscal position to be in the range of 20-40 basis points."

Various structural macroeconomic models have also been used to estimate the effects of government debt/deficits on interest rates. Gale and Orszag (2003) show that using these models, 10-year bond yields change between 5 and 220 basis points after increasing the *deficit* by 1% of GDP.

D. Other Potential Economic Impacts of Government Debt

A comprehensive review of the effects of government debt on the economy would also include an evaluation of various factors outside the scope of the three Gale and Orszag (2003) approaches described above. The following are other effects that have been identified in the literature.

1. Risk Premiums and the Size of the Federal Debt

The interest rate on debt reflects the expectation of repayment and the fear of default or devaluation. An increase in debt may lead to an increased fear of default, in which case risk premiums should rise. The country also becomes more susceptible to a crisis of international confidence and the depreciation of the currency (see Marris (1985) and Krugman (1991)). According to Trumen (2001), "The largest international risk with respect to paying down the debt is that a failure to carry it through undermines international confidence in US economic and financial policies."

Krishnamurthy and Vissing-Jorgensen (2010) estimate the discount at which U.S. government debt trades (in comparison to corporate bonds) due to its safety and liquidity. They find that this discount is influenced by both the debt-to-GDP ratio and the amount of foreign holdings. Historically, an average "convenience" yield for the period from 1926 to 2008 was 72 basis points, 46 of which were driven by liquidity, and 26 which were due to safety. This result suggests a reduced deficit (debt-GDP ratio) will drive up the liquidity premium and drive down the interest rate.

2. Impacts of the Federal Debt on Inflation

Budget deficits can lead to increased inflation because of expectations of future actions by the central bank. Paul Volcker told Congress in 1985 "… the actual and prospective size of the budget deficit ... heightens skepticism about our ability to control the money supply and contain inflation." Alan Greenspan said in 1995 that he expected "… a substantial reduction in the long-term prospective deficit of the United States will significantly lower very long-term inflation expectations *vis-a-vis* other countries." Sargent (1983) explains that inflation can fall sharply in such a country when government borrowing is reduced and the central bank commits not to finance future deficits (Elmendorf and Mankiw (1998)).

3. Future Distortionary Taxes and Federal Debt

An increase in budget deficits may imply that taxes need to be raised in the future to service the debt. Because taxes are generally distortionary, these future tax increases will lead to losses in economic efficiency.

If taxes are higher in the future, the loss in economic efficiency due to the distortionary taxes will be larger than it would be for an increase in taxes today if the marginal efficiency loss increases with the tax rates, as economic theory predicts.

Of course, if lump sum taxes are implemented, this effect disappears because these taxes are not distortionary. In addition, if GDP growth is higher than the long-run government interest rate, the government may be able to continue to rollover its debt forever (Ball and Mankiw, 1995).

4. Policy Uncertainty and Federal Debt

Policy uncertainty increases if deficits are accumulated at an unsustainable pace. This uncertainty can be a hindrance to economic performance because it makes long-term planning difficult. As Gale and Orszag (2003) note,

> *Long-term deficits create significant uncertainty… After all, the government cannot continue to run deficits so large that the public debt grows faster than output… What specific taxes will be raised? What specific spending programs will be reduced? Will the government be forced to resort to extreme measures, such as printing money to finance deficits?*

5. International Leadership and the Federal Debt

There have also been suggestions in the literature that a nation’s borrowing status corresponds with its ability to provide leadership. For example, Friedman (1988) asserted:

> *World power and influence have historically accrued to creditor countries. It is not coincidental that America emerged as a world power simultaneously with our transition from a debtor nation ... to a creditor supplying investment capital to the rest of the world.* (p. 13)

6. Distributional Impacts of the Federal Debt

The accumulation of federal debt does not necessarily increase or reduce welfare, but it has clear distributional impacts across types of individuals and periods in time. The winners from budget deficits are current taxpayers and future owners of capital (because the marginal product of capital rises), whereas the losers are future taxpayers and future workers (because real wages fall) (Ball and Mankiw, 1995).

E. Summary

Theoretical and empirical studies have led some economists to assert that there is no relationship between government debt and interest rates and still others to conclude that there is a strong positive relationship. Nevertheless, if a single parameter must be selected to govern this relationship, it should be grounded in economy theory, backed by empirical results, and not at odds with historical experience.

We use the Engen and Hubbard (2005) study for our empirical estimate of the relationship between changes in Federal government debt and changes in the interest rate; the resulting changes in the interest rate are used to calculate the effects on Federal debt payments. Engen and Hubbard (2005) find that a change in government debt equal to 1% of GDP results in a change in long-term interest rates of roughly 3 basis points. The study is a relatively recent and comprehensive review of the literature that is solely devoted to the relationship between government debt and interest rates. The result of debt having a small positive effect on long-term interest rates is arguably more plausible than claims of either no effect of government debt (which many economics would say is inconsistent with economic theory) or a large effect of debt (which is arguably inconsistent with recent historical experience of large increases in Federal debt corresponding with decreases in interest rates).

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APPENDIX D. REGIONAL RESULTS

This appendix includes additional regional results for each of the 11 macroeconomic regions in the N_{ew}ERA model. The initial figures contain results across regions. The subsequent figures include a set of results for each of the 11 regions.

Figure 44: Gross Regional Product (Percentage Change from Baseline)

Region	Present Value	2013	2023	2033	2043	2053
$20 Tax Case						
Arizona and Mountain States	-1.3%	-1.5%	-1.2%	-1.2%	-1.3%	-1.4%
California	-0.4%	-0.3%	-0.4%	-0.5%	-0.5%	-0.6%
Florida	-0.2%	-0.1%	-0.2%	-0.1%	-0.1%	-0.2%
Mid-Atlantic	-0.6%	-0.5%	-0.5%	-0.6%	-0.7%	-0.8%
Mid-America	-0.5%	-0.7%	-0.4%	-0.4%	-0.6%	-0.7%
Mississippi Valley	-0.5%	-0.5%	-0.4%	-0.4%	-0.5%	-0.6%
New York/New England	-0.4%	0.0%	-0.4%	-0.5%	-0.6%	-0.6%
Pacific Northwest	-0.4%	-0.5%	-0.4%	-0.4%	-0.3%	-0.3%
Southeast	-0.4%	-0.6%	-0.4%	-0.4%	-0.3%	-0.3%
Texas, Oklahoma, Louisiana	-0.1%	0.4%	-0.2%	-0.1%	-0.3%	-0.6%
Upper Midwest	-0.7%	-0.9%	-0.6%	-0.6%	-0.6%	-0.6%
U.S.	**-0.5%**	**-0.4%**	**-0.5%**	**-0.5%**	**-0.5%**	**-0.6%**
80% Reduction Tax Case						
Arizona and Mountain States	-2.6%	-2.2%	-1.5%	-2.3%	-4.3%	-5.1%
California	-1.2%	-0.1%	-0.4%	-1.0%	-2.7%	-4.1%
Florida	-0.5%	0.2%	-0.1%	-0.4%	-1.4%	-2.2%
Mid-Atlantic	-1.4%	-0.5%	-0.6%	-1.2%	-2.9%	-4.3%
Mid-America	-1.3%	-0.9%	-0.4%	-1.1%	-2.6%	-3.4%
Mississippi Valley	-1.0%	-0.4%	-0.3%	-0.8%	-2.2%	-3.2%
New York/New England	-1.1%	0.3%	-0.4%	-1.0%	-2.7%	-4.0%
Pacific Northwest	-1.2%	-0.5%	-0.5%	-1.0%	-2.5%	-3.4%
Southeast	-0.8%	-0.6%	-0.4%	-0.7%	-1.6%	-2.2%
Texas, Oklahoma, Louisiana	-1.3%	0.0%	-0.4%	-1.0%	-3.1%	-4.2%
Upper Midwest	-1.1%	-1.1%	-0.6%	-0.8%	-1.8%	-2.6%
U.S.	**-1.2%**	**-0.4%**	**-0.5%**	**-1.0%**	**-2.5%**	**-3.6%**

Present value calculated using a 5% real discount rate.

Figure 45: Delivered Residential Electricity Prices (Percentage Change from Baseline)

Region	**2013**	**2023**	**2033**	**2043**	**2053**
$20 Tax Case					
Arizona and Mountain States	12%	12%	15%	23%	19%
California	7.7%	11%	12%	14%	16%
Florida	10%	10%	17%	18%	19%
Mid-Atlantic	15%	10%	17%	22%	19%
Mid-America	9.3%	15%	20%	22%	18%
Mississippi Valley	14%	15%	19%	20%	21%
New York/New England	9.4%	7.7%	9.6%	12%	15%
Pacific Northwest	10%	12%	15%	22%	18%
Southeast	14%	10%	18%	22%	22%
Texas, Oklahoma, Louisiana	10%	14%	17%	24%	20%
Upper Midwest	13%	12%	17%	24%	21%
U.S.	**12%**	**12%**	**16%**	**21%**	**20%**
80% Reduction Tax Case					
Arizona and Mountain States	11%	20%	29%	60%	41%
California	11%	12%	21%	46%	31%
Florida	10%	16%	34%	65%	44%
Mid-Atlantic	17%	19%	34%	65%	46%
Mid-America	9.2%	25%	31%	54%	35%
Mississippi Valley	13%	24%	27%	61%	43%
New York/New England	9.1%	9.8%	19%	48%	33%
Pacific Northwest	11%	15%	29%	59%	35%
Southeast	16%	17%	36%	71%	51%
Texas, Oklahoma, Louisiana	10%	17%	29%	62%	43%
Upper Midwest	15%	20%	34%	66%	42%
U.S.	**13%**	**18%**	**30%**	**61%**	**42%**

Figure 46: Electricity Demand (Percentage Change from Baseline)

Region	2013	2023	2033	2043	2053
$20 Tax Case					
Arizona and Mountain States	-2.7%	-8.3%	-9.9%	-14%	-12%
California	-1.2%	-6.4%	-8.0%	-8.9%	-10%
Florida	-2.0%	-6.5%	-11%	-11%	-12%
Mid-Atlantic	-2.3%	-5.8%	-10%	-12%	-11%
Mid-America	-2.9%	-12%	-14%	-14%	-12%
Mississippi Valley	-3.3%	-10%	-13%	-13%	-13%
New York/New England	-1.8%	-5.0%	-6.6%	-8.5%	-10%
Pacific Northwest	-2.2%	-8.0%	-9.7%	-13%	-11%
Southeast	-2.5%	-6.6%	-11%	-13%	-12%
Texas, Oklahoma, Louisiana	-2.3%	-8.6%	-11%	-14%	-12%
Upper Midwest	-2.5%	-7.6%	-11%	-14%	-12%
U.S.	**-2.4%**	**-7.7%**	**-11%**	**-12%**	**-12%**
80% Reduction Tax Case					
Arizona and Mountain States	-2.7%	-12%	-17%	-28%	-25%
California	-1.7%	-7.3%	-13%	-23%	-21%
Florida	-1.9%	-9.6%	-19%	-29%	-23%
Mid-Atlantic	-2.4%	-9.6%	-18%	-28%	-25%
Mid-America	-2.8%	-17%	-19%	-28%	-25%
Mississippi Valley	-3.1%	-15%	-17%	-29%	-27%
New York/New England	-1.7%	-6.2%	-12%	-25%	-22%
Pacific Northwest	-2.2%	-9.8%	-16%	-27%	-23%
Southeast	-2.6%	-9.6%	-19%	-29%	-26%
Texas, Oklahoma, Louisiana	-2.4%	-10%	-17%	-29%	-27%
Upper Midwest	-2.6%	-11%	-18%	-29%	-26%
U.S.	**-2.4%**	**-11%**	**-17%**	**-28%**	**-25%**

Figure 47: Coal Use in Electricity (Change from Baseline, in Quadrillion Btu)

Region	2013	2023	2033	2043	2053
$20 Tax Case					
Arizona and Mountain States	-0.3	-0.8	-0.7	-0.6	-1.0
California	0.0	0.0	0.0	0.0	0.0
Florida	-0.1	-0.5	-0.6	-0.5	-0.7
Mid-Atlantic	-0.3	-0.9	-0.9	-0.9	-1.0
Mid-America	-0.2	-0.6	-0.6	-0.6	-0.8
Mississippi Valley	-0.6	-1.4	-1.5	-1.4	-1.8
New York/New England	-0.1	-0.2	-0.3	-0.2	-0.3
Pacific Northwest	-0.1	0.0	0.0	0.0	-0.1
Southeast	-0.6	-2.0	-2.4	-2.4	-3.0
Texas, Oklahoma, Louisiana	-0.2	-0.8	-0.9	-0.8	-1.4
Upper Midwest	-0.4	-0.8	-0.9	-0.8	-1.8
U.S.	**-2.8**	**-8.2**	**-9.0**	**-8.2**	**-11.8**
80% Reduction Tax Case					
Arizona and Mountain States	-0.3	-1.1	-1.9	-2.2	-2.2
California	0.0	0.0	0.0	0.0	0.0
Florida	-0.1	-0.5	-0.7	-0.8	-0.8
Mid-Atlantic	-0.2	-1.1	-1.4	-1.6	-1.6
Mid-America	-0.3	-0.8	-1.5	-1.8	-1.8
Mississippi Valley	-0.6	-2.1	-2.9	-3.2	-3.2
New York/New England	-0.1	-0.2	-0.3	-0.3	-0.3
Pacific Northwest	-0.1	0.0	-0.1	-0.1	-0.1
Southeast	-0.6	-2.4	-3.7	-4.0	-4.0
Texas, Oklahoma, Louisiana	-0.2	-1.2	-2.1	-2.2	-2.2
Upper Midwest	-0.4	-1.1	-3.4	-4.3	-4.3
U.S.	**-2.7**	**-10.6**	**-18.0**	**-20.4**	**-20.5**

Figure 48: Natural Gas Use in Electricity (Change from Baseline, in Quadrillion Btu)

Region	**2013**	**2023**	**2033**	**2043**	**2053**
$20 Tax Case					
Arizona and Mountain States	0.1	0.1	-0.1	0.0	-0.8
California	0.0	0.0	0.1	-0.2	-0.1
Florida	0.0	0.1	0.0	0.0	0.0
Mid-Atlantic	0.1	0.1	0.0	0.0	0.0
Mid-America	0.0	0.1	0.1	0.1	0.2
Mississippi Valley	0.2	0.4	0.3	0.1	0.2
New York/New England	0.1	0.0	0.0	-0.1	-0.4
Pacific Northwest	0.0	0.0	0.0	-0.3	-0.3
Southeast	0.3	0.5	0.5	0.0	-0.2
Texas, Oklahoma, Louisiana	0.2	0.3	-0.2	-0.6	-0.3
Upper Midwest	0.1	0.0	0.0	-0.1	-0.3
U.S.	**1.2**	**1.8**	**0.7**	**-1.1**	**-2.0**
80% Reduction Tax Case					
Arizona and Mountain States	0.1	0.2	0.5	-0.4	-0.4
California	0.0	0.0	0.0	-1.1	-0.9
Florida	0.0	0.1	0.0	-0.4	-0.3
Mid-Atlantic	0.1	0.1	0.1	-0.3	-0.2
Mid-America	0.0	0.2	0.6	0.8	0.9
Mississippi Valley	0.2	0.6	0.7	0.3	0.6
New York/New England	0.1	0.1	0.0	-0.6	-0.9
Pacific Northwest	0.0	0.0	0.0	-0.6	-0.6
Southeast	0.3	0.8	0.9	-0.5	-0.8
Texas, Oklahoma, Louisiana	0.2	0.6	0.8	-0.2	0.0
Upper Midwest	0.1	0.1	0.1	0.2	0.3
U.S.	**1.2**	**2.7**	**3.6**	**-2.8**	**-2.2**

Figure 49: Regional Results for Arizona and Mountain States

Carbon Tax Rates and Carbon Emissions

	2013	2023	2033	2043	2053
Carbon Tax Rate (2012$/metric ton of CO_2)					
$20 Tax	$20	$30	$44	$65	$96
80% Reduction	$20	$40	$90	$350	$1,000
Carbon Emissions (MM Metric Tons of CO_2)					
$20 Tax	410	370	360	380	320
80% Reduction	410	340	270	160	120
Carbon Tax Costs (Billions of 2012$)					
$20 Tax	$8	$11	$16	$25	$31
80% Reduction	$8	$14	$24	$56	$120

Fuel Price Impacts (Inclusive of Carbon Tax)

	2013	2023	2033	2043	2053
Wellhead Natural Gas Prices (% Change from Baseline)					
$20 Tax	44%	33%	39%	39%	45%
80% Reduction	44%	49%	86%	210%	500%
Residential Delivered Electricity Prices (% Change from Baseline)					
$20 Tax	12%	12%	15%	23%	19%
80% Reduction	11%	20%	29%	60%	41%
Gasoline Prices (% Change from Baseline)					
$20 Tax	6.4%	7.7%	10%	13%	17%
80% Reduction	7.4%	9.3%	18%	60%	164%

Gross Regional Product

	2013	2023	2033	2043	2053
GRP (% Change from Baseline)					
$20 Tax	-1.5%	-1.2%	-1.2%	-1.3%	-1.4%
80% Reduction	-2.2%	-1.5%	-2.3%	-4.3%	-5.1%
Consumption (% Change from Baseline)					
$20 Tax	-1.0%	-1.1%	-1.1%	-1.2%	-1.2%
80% Reduction	-1.7%	-1.9%	-2.2%	-2.9%	-3.8%
Change in Consumption per Household (2012$/Household)					
$20 Tax	-$840	-$970	-$950	-$1,010	-$1,040
80% Reduction	-$1,480	-$1,700	-$1,850	-$2,470	-$3,390
Investment (% Change from Baseline)					
$20 Tax	-4.6%	-2.0%	-1.3%	-1.6%	-1.4%
80% Reduction	-5.4%	-2.7%	-2.4%	-10%	-9.4%

Fuel Consumption

	2013	2023	2033	2043	2053
Coal Consumption (Quadrillion Btu)					
Baseline	2.2	2.4	2.3	2.3	2.4
$20 Tax	1.9	1.5	1.6	1.8	1.5
80% Reduction	1.9	1.3	0.4	0.2	0.3
Natural Gas Consumption (Quadrillion Btu)					
Baseline	1.6	1.8	2.0	2.0	2.5
$20 Tax	1.7	1.8	1.8	2.0	1.7
80% Reduction	1.7	1.9	2.4	1.3	1.7
Gasoline (Billions of Gallons)					
Baseline	8.0	7.3	7.0	6.9	6.7
$20 Tax	8.0	7.1	6.7	6.5	6.2
80% Reduction	7.9	7.0	6.5	5.5	4.2

Regional Results for Arizona and Mountain States

Electricity Sector Impacts

	2013	2023	2033	2043	2053
Coal Generator Retirements (GW)					
$20 Tax	0.7	9.1	9.3	9.3	11
80% Reduction	0.7	13	15	27	27
Total Electricity Demand (% Change from Baseline)					
$20 Tax	-2.7%	-8.3%	-9.9%	-14%	-12%
80% Reduction	-2.7%	-12%	-17%	-28%	-25%

Labor Impacts

	2013	2023	2033	2043	2053
Wage Rate (% Change from Baseline)					
$20 Tax	-1.6%	-1.5%	-1.4%	-1.6%	-1.7%
80% Reduction	-2.0%	-2.0%	-2.5%	-5.6%	-8.5%
Job-Equivalents (Change from Baseline in Thousands)					
$20 Tax	-180	-180	-190	-250	-290
80% Reduction	-210	-220	-340	-890	-1,490

Welfare

	2013
Welfare (% Change from Baseline)	
$20 Tax	-0.57%
80% Reduction	-1.29%

Figure 50: Regional Results for California

Carbon Tax Rates and Carbon Emissions

	2013	2023	2033	2043	2053
Carbon Tax Rate (2012$/metric ton of CO_2)					
$20 Tax	$20	$30	$44	$65	$96
80% Reduction	$20	$40	$90	$350	$1,000
Carbon Emissions (MM Metric Tons of CO_2)					
$20 Tax	370	360	370	390	370
80% Reduction	370	350	340	270	190
Carbon Tax Costs (Billions of 2012$)					
$20 Tax	$7	$11	$16	$25	$36
80% Reduction	$7	$14	$31	$95	$190

Gross Regional Product

	2013	2023	2033	2043	2053
GRP (% Change from Baseline)					
$20 Tax	-0.3%	-0.4%	-0.5%	-0.5%	-0.6%
80% Reduction	-0.1%	-0.4%	-1.0%	-2.7%	-4.1%
Consumption (% Change from Baseline)					
$20 Tax	0.3%	-0.1%	-0.1%	-0.2%	-0.2%
80% Reduction	0.5%	-0.2%	-0.5%	-1.4%	-2.4%
Change in Consumption per Household (2012$/Household)					
$20 Tax	$310	-$90	-$120	-$250	-$230
80% Reduction	$510	-$340	-$590	-$1,490	-$2,890
Investment (% Change from Baseline)					
$20 Tax	0.2%	-0.7%	-0.2%	-0.9%	-0.9%
80% Reduction	1.7%	-0.9%	-2.2%	-5.4%	-8.2%

Regional Results for California

Fuel Price Impacts (Inclusive of Carbon Tax)

	2013	2023	2033	2043	2053
Wellhead Natural Gas Prices (% Change from Baseline)					
$20 Tax	44%	33%	39%	39%	45%
80% Reduction	44%	49%	86%	210%	500%
Residential Delivered Electricity Prices (% Change from Baseline)					
$20 Tax	7.7%	11%	12%	14%	16%
80% Reduction	11%	12%	21%	46%	31%
Gasoline Prices (% Change from Baseline)					
$20 Tax	5.9%	7.4%	10%	13%	17%
80% Reduction	6.2%	9.0%	17%	60%	164%

Fuel Consumption

	2013	2023	2033	2043	2053
Coal Consumption (Quadrillion Btu)					
Baseline	0.1	0.1	0.1	0.1	0.3
$20 Tax	0.0	0.0	0.2	0.3	0.4
80% Reduction	0.0	0.1	0.2	0.4	0.6
Natural Gas Consumption (Quadrillion Btu)					
Baseline	2.5	2.6	2.8	3.5	3.8
$20 Tax	2.5	2.5	2.9	3.3	3.6
80% Reduction	2.5	2.5	2.6	2.1	2.3
Gasoline (Billions of Gallons)					
Baseline	14	12	12	12	11
$20 Tax	14	12	11	11	11
80% Reduction	14	12	11	9.5	7.2

Electricity Sector Impacts

	2013	2023	2033	2043	2053
Coal Generator Retirements (GW)					
$20 Tax	0.0	0.0	0.0	0.0	0.0
80% Reduction	0.0	0.0	0.0	0.4	0.4
Total Electricity Demand (% Change from Baseline)					
$20 Tax	-1.2%	-6.4%	-8.0%	-8.9%	-10%
80% Reduction	-1.7%	-7.3%	-13%	-23%	-21%

Labor Impacts

	2013	2023	2033	2043	2053
Wage Rate (% Change from Baseline)					
$20 Tax	-0.2%	-0.6%	-0.5%	-0.6%	-0.8%
80% Reduction	0.1%	-0.6%	-1.0%	-3.2%	-6.2%
Job-Equivalents (Change from Baseline in Thousands)					
$20 Tax	-50	-190	-190	-250	-320
80% Reduction	0	-200	-330	-1,070	-2,060

Welfare

	2013
Welfare (% Change from Baseline)	
$20 Tax	0.06%
80% Reduction	-0.19%

Figure 51: Regional Results for Florida

Carbon Tax Rates and Carbon Emissions

	2013	2023	2033	2043	2053
Carbon Tax Rate (2012$/metric ton of CO_2)					
$20 Tax	$20	$30	$44	$65	$96
80% Reduction	$20	$40	$90	$350	$1,000
Carbon Emissions (MM Metric Tons of CO_2)					
$20 Tax	200	180	170	160	130
80% Reduction	200	180	150	100	60
Carbon Tax Costs (Billions of 2012$)					
$20 Tax	$4	$5	$7	$10	$12
80% Reduction	$4	$7	$14	$35	$60

Gross Regional Product

	2013	2023	2033	2043	2053
GRP (% Change from Baseline)					
$20 Tax	-0.1%	-0.2%	-0.1%	-0.1%	-0.2%
80% Reduction	0.2%	-0.1%	-0.4%	-1.4%	-2.2%
Consumption (% Change from Baseline)					
$20 Tax	0.3%	-0.1%	-0.1%	-0.2%	-0.2%
80% Reduction	0.6%	-0.1%	-0.3%	-1.0%	-2.0%
Change in Consumption per Household (2012$/Household)					
$20 Tax	$270	-$60	-$50	-$150	-$140
80% Reduction	$540	-$110	-$230	-$770	-$1,990
Investment (% Change from Baseline)					
$20 Tax	-1.5%	-2.7%	-2.8%	-1.1%	-1.7%
80% Reduction	0.1%	-3.3%	-1.1%	-3.0%	-5.2%

Fuel Price Impacts (Inclusive of Carbon Tax)

	2013	2023	2033	2043	2053
Wellhead Natural Gas Prices (% Change from Baseline)					
$20 Tax	44%	33%	39%	39%	45%
80% Reduction	44%	49%	86%	210%	500%
Residential Delivered Electricity Prices (% Change from Baseline)					
$20 Tax	10%	10%	17%	18%	19%
80% Reduction	10%	16%	34%	65%	44%
Gasoline Prices (% Change from Baseline)					
$20 Tax	6.0%	7.4%	10%	13%	17%
80% Reduction	6.3%	8.9%	17%	61%	167%

Fuel Consumption

	2013	2023	2033	2043	2053
Coal Consumption (Quadrillion Btu)					
Baseline	0.3	0.7	0.8	0.8	0.9
$20 Tax	0.2	0.2	0.2	0.4	0.3
80% Reduction	0.2	0.2	0.1	0.1	0.2
Natural Gas Consumption (Quadrillion Btu)					
Baseline	1.4	1.2	1.1	0.7	0.6
$20 Tax	1.4	1.2	1.1	0.8	0.6
80% Reduction	1.4	1.3	1.2	0.4	0.4
Gasoline (Billions of Gallons)					
Baseline	7.4	6.7	6.4	6.3	6.2
$20 Tax	7.4	6.6	6.2	6.0	5.7
80% Reduction	7.4	6.5	6.0	5.1	3.9

Regional Results for Florida

Electricity Sector Impacts

	2013	2023	2033	2043	2053
Coal Generator Retirements (GW)					
$20 Tax	0.0	5.8	5.8	5.8	6.2
80% Reduction	0.0	6.5	10	11	11
Total Electricity Demand (% Change from Baseline)					
$20 Tax	-2.0%	-6.5%	-11%	-11%	-12%
80% Reduction	-1.9%	-9.6%	-19%	-29%	-23%

Labor Impacts

	2013	2023	2033	2043	2053
Wage Rate (% Change from Baseline)					
$20 Tax	-0.5%	-0.7%	-0.7%	-0.8%	-0.9%
80% Reduction	-0.1%	-0.9%	-1.4%	-3.6%	-5.6%
Job-Equivalents (Change from Baseline in Thousands)					
$20 Tax	-50	-110	-120	-140	-170
80% Reduction	-10	-130	-210	-550	-900

Welfare

	2013
Welfare (% Change from Baseline)	
$20 Tax	-0.07%
80% Reduction	-0.35%

Figure 52: Regional Results for Mid-Atlantic

Carbon Tax Rates and Carbon Emissions

	2013	2023	2033	2043	2053
Carbon Tax Rate (2012$/metric ton of CO_2)					
$20 Tax	$20	$30	$44	$65	$96
80% Reduction	$20	$40	$90	$350	$1,000
Carbon Emissions (MM Metric Tons of CO_2)					
$20 Tax	430	370	350	350	320
80% Reduction	440	340	290	220	150
Carbon Tax Costs (Billions of 2012$)					
$20 Tax	$9	$11	$15	$23	$31
80% Reduction	$9	$14	$26	$77	$150

Gross Regional Product

	2013	2023	2033	2043	2053
GRP (% Change from Baseline)					
$20 Tax	-0.5%	-0.5%	-0.6%	-0.7%	-0.8%
80% Reduction	-0.5%	-0.6%	-1.2%	-2.9%	-4.3%
Consumption (% Change from Baseline)					
$20 Tax	0.0%	-0.4%	-0.4%	-0.5%	-0.5%
80% Reduction	0.0%	-0.7%	-1.0%	-1.8%	-2.9%
Change in Consumption per Household (2012$/Household)					
$20 Tax	-$20	-$460	-$470	-$580	-$590
80% Reduction	-$30	-$820	-$1,060	-$1,910	-$3,450
Investment (% Change from Baseline)					
$20 Tax	-4.1%	-1.3%	-1.0%	-1.7%	-1.0%
80% Reduction	-2.2%	1.8%	-1.7%	-7.1%	-8.6%

Regional Results for Mid-Atlantic

Fuel Price Impacts (Inclusive of Carbon Tax)

	2013	2023	2033	2043	2053
Wellhead Natural Gas Prices (% Change from Baseline)					
$20 Tax	44%	33%	39%	39%	45%
80% Reduction	44%	49%	86%	210%	500%
Residential Delivered Electricity Prices (% Change from Baseline)					
$20 Tax	15%	10%	17%	22%	19%
80% Reduction	17%	19%	34%	65%	46%
Gasoline Prices (% Change from Baseline)					
$20 Tax	6.1%	7.6%	10%	13%	17%
80% Reduction	6.6%	9.1%	18%	60%	165%

Fuel Consumption

	2013	2023	2033	2043	2053
Coal Consumption (Quadrillion Btu)					
Baseline	1.6	1.8	1.8	1.9	2.0
$20 Tax	1.4	0.8	0.9	1.1	1.0
80% Reduction	1.4	0.7	0.4	0.3	0.5
Natural Gas Consumption (Quadrillion Btu)					
Baseline	1.8	1.9	1.8	1.8	1.7
$20 Tax	2.0	1.9	1.8	1.8	1.7
80% Reduction	1.9	1.9	1.8	1.2	1.1
Gasoline (Billions of Gallons)					
Baseline	13	11	11	11	10
$20 Tax	13	11	10	10	9.7
80% Reduction	13	11	10	8.7	6.7

Electricity Sector Impacts

	2013	2023	2033	2043	2053
Coal Generator Retirements (GW)					
$20 Tax	0.2	9.0	10	10	13
80% Reduction	0.2	11	20	24	24
Total Electricity Demand (% Change from Baseline)					
$20 Tax	-2.3%	-5.8%	-10%	-12%	-11%
80% Reduction	-2.4%	-9.6%	-18%	-28%	-25%

Labor Impacts

	2013	2023	2033	2043	2053
Wage Rate (% Change from Baseline)					
$20 Tax	-0.9%	-0.8%	-0.8%	-0.9%	-1.0%
80% Reduction	-0.7%	-1.1%	-1.6%	-3.9%	-6.7%
Job-Equivalents (Change from Baseline in Thousands)					
$20 Tax	-150	-180	-200	-260	-300
80% Reduction	-120	-240	-360	-970	-1,730

Welfare

	2013
Welfare (% Change from Baseline)	
$20 Tax	-0.12%
80% Reduction	-0.45%

Figure 53: Regional Results for Mid-America

Carbon Tax Rates and Carbon Emissions

	2013	2023	2033	2043	2053
Carbon Tax Rate (2012$/metric ton of CO_2)					
$20 Tax	$20	$30	$44	$65	$96
80% Reduction	$20	$40	$90	$350	$1,000
Carbon Emissions (MM Metric Tons of CO_2)					
$20 Tax	340	300	310	320	290
80% Reduction	330	280	210	150	110
Carbon Tax Costs (Billions of 2012$)					
$20 Tax	$7	$9	$14	$21	$28
80% Reduction	$7	$11	$19	$53	$110

Gross Regional Product

	2013	2023	2033	2043	2053
GRP (% Change from Baseline)					
$20 Tax	-0.7%	-0.4%	-0.4%	-0.6%	-0.7%
80% Reduction	-0.9%	-0.4%	-1.1%	-2.6%	-3.4%
Consumption (% Change from Baseline)					
$20 Tax	-0.3%	-0.5%	-0.5%	-0.6%	-0.6%
80% Reduction	-0.5%	-0.9%	-1.1%	-1.8%	-2.6%
Change in Consumption per Household (2012$/Household)					
$20 Tax	-$290	-$480	-$450	-$540	-$560
80% Reduction	-$520	-$900	-$1,050	-$1,590	-$2,550
Investment (% Change from Baseline)					
$20 Tax	-6.0%	-1.1%	-0.3%	-1.2%	-1.7%
80% Reduction	-4.5%	0.7%	-2.3%	-8.5%	-9.0%

Fuel Price Impacts (Inclusive of Carbon Tax)

	2013	2023	2033	2043	2053
Wellhead Natural Gas Prices (% Change from Baseline)					
$20 Tax	44%	33%	39%	39%	44%
80% Reduction	43%	49%	85%	210%	500%
Residential Delivered Electricity Prices (% Change from Baseline)					
$20 Tax	9.3%	15%	20%	22%	18%
80% Reduction	9.2%	25%	31%	54%	35%
Gasoline Prices (% Change from Baseline)					
$20 Tax	6.1%	7.4%	9.8%	12%	17%
80% Reduction	6.7%	8.8%	17%	60%	165%

Fuel Consumption

	2013	2023	2033	2043	2053
Coal Consumption (Quadrillion Btu)					
Baseline	1.8	1.9	2.0	2.1	2.1
$20 Tax	1.6	1.3	1.4	1.5	1.3
80% Reduction	1.5	1.1	0.5	0.2	0.3
Natural Gas Consumption (Quadrillion Btu)					
Baseline	1.3	1.3	1.3	1.4	1.5
$20 Tax	1.3	1.3	1.3	1.5	1.7
80% Reduction	1.3	1.3	1.8	1.9	1.9
Gasoline (Billions of Gallons)					
Baseline	6.9	6.2	5.9	5.9	5.7
$20 Tax	6.8	6.1	5.7	5.6	5.3
80% Reduction	6.8	6.0	5.6	4.8	3.7

Regional Results for Mid-America

Electricity Sector Impacts

	2013	2023	2033	2043	2053
Coal Generator Retirements (GW)					
$20 Tax	0.0	8.8	8.8	8.8	11
80% Reduction	0.0	12	19	25	25
Total Electricity Demand (% Change from Baseline)					
$20 Tax	-2.9%	-12%	-14%	-14%	-12%
80% Reduction	-2.8%	-17%	-19%	-28%	-25%

Labor Impacts

	2013	2023	2033	2043	2053
Wage Rate (% Change from Baseline)					
$20 Tax	-1.1%	-1.3%	-1.4%	-1.5%	-1.5%
80% Reduction	-1.0%	-1.8%	-2.4%	-5.4%	-8.5%
Job-Equivalents (Change from Baseline in Thousands)					
$20 Tax	-100	-150	-170	-210	-230
80% Reduction	-90	-180	-280	-730	-1,250

Welfare

	2013
Welfare (% Change from Baseline)	
$20 Tax	-0.32%
80% Reduction	-0.89%

Figure 54: Regional Results for Mississippi Valley

Carbon Tax Rates and Carbon Emissions

	2013	2023	2033	2043	2053
Carbon Tax Rate (2012$/metric ton of CO_2)					
$20 Tax	$20	$30	$44	$65	$96
80% Reduction	$20	$40	$90	$350	$1,000
Carbon Emissions (MM Metric Tons of CO_2)					
$20 Tax	650	560	550	550	490
80% Reduction	650	490	410	290	200
Carbon Tax Costs (Billions of 2012$)					
$20 Tax	$13	$17	$24	$36	$47
80% Reduction	$13	$20	$37	$102	$200

Gross Regional Product

	2013	2023	2033	2043	2053
GRP (% Change from Baseline)					
$20 Tax	-0.5%	-0.4%	-0.4%	-0.5%	-0.6%
80% Reduction	-0.4%	-0.3%	-0.8%	-2.2%	-3.2%
Consumption (% Change from Baseline)					
$20 Tax	-0.1%	-0.3%	-0.4%	-0.4%	-0.5%
80% Reduction	-0.1%	-0.6%	-0.8%	-1.4%	-2.3%
Change in Consumption per Household (2012$/Household)					
$20 Tax	-$70	-$330	-$330	-$420	-$410
80% Reduction	-$70	-$560	-$730	-$1,200	-$2,210
Investment (% Change from Baseline)					
$20 Tax	-7.3%	0.3%	-0.1%	-1.4%	-1.2%
80% Reduction	-6.9%	2.5%	-1.6%	-6.9%	-9.1%

Regional Results for Mississippi Valley

Fuel Price Impacts (Inclusive of Carbon Tax)

	2013	2023	2033	2043	2053
Wellhead Natural Gas Prices (% Change from Baseline)					
$20 Tax	44%	33%	39%	39%	45%
80% Reduction	44%	49%	86%	210%	500%
Residential Delivered Electricity Prices (% Change from Baseline)					
$20 Tax	14%	15%	19%	20%	21%
80% Reduction	13%	24%	27%	61%	43%
Gasoline Prices (% Change from Baseline)					
$20 Tax	5.8%	7.3%	9.8%	12%	17%
80% Reduction	6.3%	8.7%	17%	59%	164%

Fuel Consumption

	2013	2023	2033	2043	2053
Coal Consumption (Quadrillion Btu)					
Baseline	3.4	3.4	3.5	3.6	3.7
$20 Tax	2.8	1.9	2.0	2.3	1.9
80% Reduction	2.8	1.3	0.7	0.3	0.5
Natural Gas Consumption (Quadrillion Btu)					
Baseline	2.5	2.6	2.7	2.8	2.9
$20 Tax	2.6	2.8	2.8	2.8	2.9
80% Reduction	2.6	2.9	3.1	2.5	2.5
Gasoline (Billions of Gallons)					
Baseline	16	14	14	14	13
$20 Tax	16	14	13	13	12
80% Reduction	16	14	13	11	8.6

Electricity Sector Impacts

	2013	2023	2033	2043	2053
Coal Generator Retirements (GW)					
$20 Tax	0.2	24	24	24	25
80% Reduction	0.2	31	35	48	48
Total Electricity Demand (% Change from Baseline)					
$20 Tax	-3.3%	-10%	-13%	-13%	-13%
80% Reduction	-3.1%	-15%	-17%	-29%	-27%

Labor Impacts

	2013	2023	2033	2043	2053
Wage Rate (% Change from Baseline)					
$20 Tax	-0.9%	-1.2%	-1.1%	-1.2%	-1.3%
80% Reduction	-0.6%	-1.5%	-1.9%	-4.8%	-7.7%
Job-Equivalents (Change from Baseline in Thousands)					
$20 Tax	-200	-300	-330	-410	-480
80% Reduction	-140	-380	-540	-1,470	-2,550

Welfare

	2013
Welfare (% Change from Baseline)	
$20 Tax	-0.23%
80% Reduction	-0.67%

Figure 55: Regional Results for New York/New England

Carbon Tax Rates and Carbon Emissions

	2013	2023	2033	2043	2053
Carbon Tax Rate (2012$/metric ton of CO_2)					
$20 Tax	$20	$30	$44	$65	$96
80% Reduction	$20	$40	$90	$350	$1,000
Carbon Emissions (MM Metric Tons of CO_2)					
$20 Tax	320	290	290	290	270
80% Reduction	320	280	270	210	130
Carbon Tax Costs (Billions of 2012$)					
$20 Tax	$6	$9	$13	$19	$26
80% Reduction	$6	$11	$24	$74	$130

Fuel Price Impacts (Inclusive of Carbon Tax)

	2013	2023	2033	2043	2053
Wellhead Natural Gas Prices (% Change from Baseline)					
$20 Tax	44%	33%	39%	39%	45%
80% Reduction	44%	49%	86%	210%	500%
Residential Delivered Electricity Prices (% Change from Baseline)					
$20 Tax	9.4%	7.7%	9.6%	12%	15%
80% Reduction	9.1%	9.8%	19%	48%	33%
Gasoline Prices (% Change from Baseline)					
$20 Tax	5.9%	7.5%	10%	13%	17%
80% Reduction	6.2%	9.1%	18%	61%	166%

Gross Regional Product

	2013	2023	2033	2043	2053
GRP (% Change from Baseline)					
$20 Tax	0.0%	-0.4%	-0.5%	-0.6%	-0.6%
80% Reduction	0.3%	-0.4%	-1.0%	-2.7%	-4.0%
Consumption (% Change from Baseline)					
$20 Tax	0.5%	0.0%	-0.1%	-0.2%	-0.2%
80% Reduction	0.8%	-0.1%	-0.4%	-1.4%	-2.4%
Change in Consumption per Household (2012$/Household)					
$20 Tax	$590	$10	-$20	-$180	-$170
80% Reduction	$950	-$150	-$440	-$1,500	-$3,190
Investment (% Change from Baseline)					
$20 Tax	3.9%	-2.4%	-1.7%	-1.3%	-1.6%
80% Reduction	5.1%	-2.9%	-2.7%	-4.6%	-7.5%

Fuel Consumption

	2013	2023	2033	2043	2053
Coal Consumption (Quadrillion Btu)					
Baseline	0.2	0.3	0.4	0.4	0.5
$20 Tax	0.1	0.1	0.1	0.2	0.3
80% Reduction	0.1	0.1	0.1	0.2	0.3
Natural Gas Consumption (Quadrillion Btu)					
Baseline	2.1	2.0	2.1	2.2	2.4
$20 Tax	2.2	2.0	2.1	2.1	2.0
80% Reduction	2.2	2.0	2.0	1.3	1.1
Gasoline (Billions of Gallons)					
Baseline	14	13	12	12	12
$20 Tax	14	12	12	11	11
80% Reduction	14	12	11	9.8	7.4

Regional Results for New York/New England

Electricity Sector Impacts

	2013	2023	2033	2043	2053
Coal Generator Retirements (GW)					
$20 Tax	0.0	2.9	2.9	3.1	3.5
80% Reduction	0.0	2.9	2.9	4.3	4.3
Total Electricity Demand (% Change from Baseline)					
$20 Tax	-1.8%	-5.0%	-6.6%	-8.5%	-10%
80% Reduction	-1.7%	-6.2%	-12%	-25%	-22%

Labor Impacts

	2013	2023	2033	2043	2053
Wage Rate (% Change from Baseline)					
$20 Tax	-0.3%	-0.5%	-0.4%	-0.4%	-0.6%
80% Reduction	0.0%	-0.6%	-0.8%	-2.6%	-4.7%
Job-Equivalents (Change from Baseline in Thousands)					
$20 Tax	-80	-170	-170	-210	-260
80% Reduction	-10	-190	-300	-870	-1,580

Welfare

	2013
Welfare (% Change from Baseline)	
$20 Tax	0.14%
80% Reduction	-0.03%

Figure 56: Regional Results for Pacific Northwest

Carbon Tax Rates and Carbon Emissions

	2013	2023	2033	2043	2053
Carbon Tax Rate (2012$/metric ton of CO_2)					
$20 Tax	$20	$30	$44	$65	$96
80% Reduction	$20	$40	$90	$350	$1,000
Carbon Emissions (MM Metric Tons of CO_2)					
$20 Tax	180	160	160	160	150
80% Reduction	180	160	150	120	90
Carbon Tax Costs (Billions of 2012$)					
$20 Tax	$4	$5	$7	$10	$14
80% Reduction	$4	$6	$14	$42	$90

Gross Regional Product

	2013	2023	2033	2043	2053
GRP (% Change from Baseline)					
$20 Tax	-0.5%	-0.4%	-0.4%	-0.3%	-0.3%
80% Reduction	-0.5%	-0.5%	-1.0%	-2.5%	-3.4%
Consumption (% Change from Baseline)					
$20 Tax	0.0%	-0.2%	-0.3%	-0.3%	-0.3%
80% Reduction	-0.2%	-0.7%	-0.9%	-1.6%	-2.5%
Change in Consumption per Household (2012$/Household)					
$20 Tax	$30	-$240	-$240	-$300	-$320
80% Reduction	-$140	-$670	-$820	-$1,440	-$2,540
Investment (% Change from Baseline)					
$20 Tax	0.5%	-0.6%	-1.2%	-0.6%	-0.8%
80% Reduction	1.8%	-1.1%	-0.9%	-6.6%	-9.1%

Regional Results for Pacific Northwest

Fuel Price Impacts (Inclusive of Carbon Tax)

	2013	2023	2033	2043	2053
Wellhead Natural Gas Prices (% Change from Baseline)					
$20 Tax	44%	33%	39%	39%	45%
80% Reduction	44%	49%	86%	210%	500%
Residential Delivered Electricity Prices (% Change from Baseline)					
$20 Tax	10%	12%	15%	22%	18%
80% Reduction	11%	15%	29%	59%	35%
Gasoline Prices (% Change from Baseline)					
$20 Tax	5.9%	7.4%	9.9%	12%	17%
80% Reduction	6.6%	9.0%	17%	60%	164%

Fuel Consumption

	2013	2023	2033	2043	2053
Coal Consumption (Quadrillion Btu)					
Baseline	0.2	0.1	0.1	0.1	0.2
$20 Tax	0.1	0.0	0.1	0.2	0.3
80% Reduction	0.1	0.1	0.1	0.2	0.3
Natural Gas Consumption (Quadrillion Btu)					
Baseline	1.0	1.0	1.1	1.4	1.7
$20 Tax	1.0	1.0	1.0	1.1	1.4
80% Reduction	1.0	1.0	1.0	0.7	0.9
Gasoline (Billions of Gallons)					
Baseline	5.2	4.7	4.5	4.4	4.3
$20 Tax	5.2	4.5	4.3	4.2	4.0
80% Reduction	5.1	4.5	4.2	3.6	2.7

Electricity Sector Impacts

	2013	2023	2033	2043	2053
Coal Generator Retirements (GW)					
$20 Tax	0.0	1.9	1.9	1.9	1.9
80% Reduction	0.0	1.9	2.0	2.2	2.2
Total Electricity Demand (% Change from Baseline)					
$20 Tax	-2.2%	-8.0%	-9.7%	-13%	-11%
80% Reduction	-2.2%	-9.8%	-16%	-27%	-23%

Labor Impacts

	2013	2023	2033	2043	2053
Wage Rate (% Change from Baseline)					
$20 Tax	-0.5%	-0.9%	-0.8%	-1.1%	-1.2%
80% Reduction	-0.4%	-1.1%	-1.7%	-4.8%	-8.1%
Job-Equivalents (Change from Baseline in Thousands)					
$20 Tax	-50	-100	-110	-160	-190
80% Reduction	-40	-120	-200	-600	-1,080

Welfare

	2013
Welfare (% Change from Baseline)	
$20 Tax	-0.09%
80% Reduction	-0.55%

Figure 57: Regional Results for Southeast

Carbon Tax Rates and Carbon Emissions

	2013	2023	2033	2043	2053
Carbon Tax Rate (2012$/metric ton of CO_2)					
$20 Tax	$20	$30	$44	$65	$96
80% Reduction	$20	$40	$90	$350	$1,000
Carbon Emissions (MM Metric Tons of CO_2)					
$20 Tax	720	630	610	600	510
80% Reduction	720	580	470	340	220
Carbon Tax Costs (Billions of 2012$)					
$20 Tax	$14	$19	$27	$39	$49
80% Reduction	$14	$23	$42	$119	$220

Fuel Price Impacts (Inclusive of Carbon Tax)

	2013	2023	2033	2043	2053
Wellhead Natural Gas Prices (% Change from Baseline)					
$20 Tax	44%	33%	39%	39%	44%
80% Reduction	44%	49%	85%	210%	500%
Residential Delivered Electricity Prices (% Change from Baseline)					
$20 Tax	14%	10%	18%	22%	22%
80% Reduction	16%	17%	36%	71%	51%
Gasoline Prices (% Change from Baseline)					
$20 Tax	6.0%	7.4%	9.9%	12%	17%
80% Reduction	6.5%	8.9%	17%	60%	165%

Gross Regional Product

	2013	2023	2033	2043	2053
GRP (% Change from Baseline)					
$20 Tax	-0.6%	-0.4%	-0.4%	-0.3%	-0.3%
80% Reduction	-0.6%	-0.4%	-0.7%	-1.6%	-2.2%
Consumption (% Change from Baseline)					
$20 Tax	-0.1%	-0.4%	-0.4%	-0.5%	-0.5%
80% Reduction	-0.2%	-0.7%	-0.9%	-1.5%	-2.3%
Change in Consumption per Household (2012$/Household)					
$20 Tax	-$130	-$400	-$380	-$450	-$450
80% Reduction	-$140	-$670	-$760	-$1,200	-$2,220
Investment (% Change from Baseline)					
$20 Tax	-6.9%	-0.2%	-2.0%	-1.0%	-1.0%
80% Reduction	-7.3%	1.4%	-1.3%	-5.0%	-8.3%

Fuel Consumption

	2013	2023	2033	2043	2053
Coal Consumption (Quadrillion Btu)					
Baseline	3.3	3.8	4.2	4.4	4.6
$20 Tax	2.7	1.8	1.9	2.1	1.6
80% Reduction	2.7	1.4	0.6	0.5	0.7
Natural Gas Consumption (Quadrillion Btu)					
Baseline	2.4	2.6	2.6	3.1	3.2
$20 Tax	2.8	2.9	3.1	3.1	3.0
80% Reduction	2.8	3.2	3.4	2.3	2.1
Gasoline (Billions of Gallons)					
Baseline	22	20	19	18	18
$20 Tax	22	19	18	18	17
80% Reduction	22	19	18	15	12

Regional Results for Southeast

Electricity Sector Impacts

	2013	2023	2033	2043	2053
Coal Generator Retirements (GW)					
$20 Tax	1.3	24	26	26	32
80% Reduction	1.3	32	47	54	54
Total Electricity Demand (% Change from Baseline)					
$20 Tax	-2.5%	-6.6%	-11%	-13%	-12%
80% Reduction	-2.6%	-9.6%	-19%	-29%	-26%

Labor Impacts

	2013	2023	2033	2043	2053
Wage Rate (% Change from Baseline)					
$20 Tax	-1.1%	-1.1%	-1.1%	-1.3%	-1.4%
80% Reduction	-1.0%	-1.4%	-2.1%	-5.1%	-7.8%
Job-Equivalents (Change from Baseline in Thousands)					
$20 Tax	-280	-340	-400	-510	-600
80% Reduction	-240	-420	-700	-1,850	-3,070

Welfare

	2013
Welfare (% Change from Baseline)	
$20 Tax	-0.29%
80% Reduction	-0.76%

Figure 58: Regional Results for Texas, Oklahoma, Louisiana

Carbon Tax Rates and Carbon Emissions

	2013	2023	2033	2043	2053
Carbon Tax Rate (2012$/metric ton of CO_2)					
$20 Tax	$20	$30	$44	$65	$96
80% Reduction	$20	$40	$90	$350	$1,000
Carbon Emissions (MM Metric Tons of CO_2)					
$20 Tax	910	830	810	820	740
80% Reduction	910	790	680	500	350
Carbon Tax Costs (Billions of 2012$)					
$20 Tax	$18	$25	$36	$53	$71
80% Reduction	$18	$32	$61	$175	$350

Gross Regional Product

	2013	2023	2033	2043	2053
GRP (% Change from Baseline)					
$20 Tax	0.4%	-0.2%	-0.1%	-0.3%	-0.6%
80% Reduction	0.0%	-0.4%	-1.0%	-3.1%	-4.2%
Consumption (% Change from Baseline)					
$20 Tax	0.0%	-0.3%	-0.3%	-0.4%	-0.4%
80% Reduction	-0.6%	-1.0%	-1.3%	-1.9%	-2.7%
Change in Consumption per Household (2012$/Household)					
$20 Tax	-$30	-$300	-$310	-$400	-$420
80% Reduction	-$610	-$1,040	-$1,180	-$1,810	-$2,800
Investment (% Change from Baseline)					
$20 Tax	-0.4%	-1.3%	-1.9%	-2.0%	-2.9%
80% Reduction	-0.2%	-2.5%	-4.8%	-14%	-16%

Regional Results for Texas, Oklahoma, Louisiana

Fuel Price Impacts (Inclusive of Carbon Tax)

	2013	2023	2033	2043	2053
Wellhead Natural Gas Prices (% Change from Baseline)					
$20 Tax	44%	33%	39%	39%	44%
80% Reduction	43%	49%	85%	210%	500%
Residential Delivered Electricity Prices (% Change from Baseline)					
$20 Tax	10%	14%	17%	24%	20%
80% Reduction	10%	17%	29%	62%	43%
Gasoline Prices (% Change from Baseline)					
$20 Tax	5.8%	7.3%	9.8%	12%	17%
80% Reduction	6.7%	8.9%	17%	60%	164%

Fuel Consumption

	2013	2023	2033	2043	2053
Coal Consumption (Quadrillion Btu)					
Baseline	2.3	2.2	2.3	2.4	2.6
$20 Tax	2.1	1.4	1.5	1.8	1.4
80% Reduction	2.1	1.1	0.5	0.5	0.8
Natural Gas Consumption (Quadrillion Btu)					
Baseline	5.3	5.8	6.1	6.5	7.1
$20 Tax	5.4	5.7	5.5	5.7	6.5
80% Reduction	5.4	5.8	6.2	5.1	5.2
Gasoline (Billions of Gallons)					
Baseline	14	13	13	12	12
$20 Tax	14	13	12	12	11
80% Reduction	14	13	12	10	7.7

Electricity Sector Impacts

	2013	2023	2033	2043	2053
Coal Generator Retirements (GW)					
$20 Tax	0.0	6.5	6.5	14	23
80% Reduction	0.0	11	17	33	33
Total Electricity Demand (% Change from Baseline)					
$20 Tax	-2.3%	-8.6%	-11%	-14%	-12%
80% Reduction	-2.4%	-10%	-17%	-29%	-27%

Labor Impacts

	2013	2023	2033	2043	2053
Wage Rate (% Change from Baseline)					
$20 Tax	-0.8%	-1.4%	-1.4%	-1.6%	-1.8%
80% Reduction	-1.1%	-1.8%	-2.6%	-6.5%	-11%
Job-Equivalents (Change from Baseline in Thousands)					
$20 Tax	-160	-330	-360	-470	-540
80% Reduction	-190	-390	-620	-1,700	-3,000

Welfare

	2013
Welfare (% Change from Baseline)	
$20 Tax	-0.23%
80% Reduction	-0.94%

Figure 59: Regional Results for Upper Midwest

Carbon Tax Rates and Carbon Emissions

	2013	2023	2033	2043	2053
Carbon Tax Rate (2012$/metric ton of CO_2)					
$20 Tax	$20	$30	$44	$65	$96
80% Reduction	$20	$40	$90	$350	$1,000
Carbon Emissions (MM Metric Tons of CO_2)					
$20 Tax	690	620	620	620	510
80% Reduction	690	600	370	230	160
Carbon Tax Costs (Billions of 2012$)					
$20 Tax	$14	$18	$27	$40	$49
80% Reduction	$14	$24	$33	$81	$160

Fuel Price Impacts (Inclusive of Carbon Tax)

	2013	2023	2033	2043	2053
Wellhead Natural Gas Prices (% Change from Baseline)					
$20 Tax	44%	33%	39%	39%	44%
80% Reduction	44%	49%	85%	210%	500%
Residential Delivered Electricity Prices (% Change from Baseline)					
$20 Tax	13%	12%	17%	24%	21%
80% Reduction	15%	20%	34%	66%	42%
Gasoline Prices (% Change from Baseline)					
$20 Tax	6.0%	7.4%	9.9%	12%	17%
80% Reduction	6.6%	8.9%	17%	59%	164%

Gross Regional Product

	2013	2023	2033	2043	2053
GRP (% Change from Baseline)					
$20 Tax	-0.9%	-0.6%	-0.6%	-0.6%	-0.6%
80% Reduction	-1.1%	-0.6%	-0.8%	-1.8%	-2.6%
Consumption (% Change from Baseline)					
$20 Tax	-0.6%	-0.8%	-0.8%	-0.9%	-0.9%
80% Reduction	-0.9%	-1.2%	-1.4%	-2.0%	-2.7%
Change in Consumption per Household (2012$/Household)					
$20 Tax	-$530	-$710	-$690	-$730	-$750
80% Reduction	-$710	-$1,070	-$1,160	-$1,510	-$2,350
Investment (% Change from Baseline)					
$20 Tax	-12%	-0.9%	-1.4%	-0.8%	-2.1%
80% Reduction	-11%	0.8%	-2.4%	-10%	-9.5%

Fuel Consumption

	2013	2023	2033	2043	2053
Coal Consumption (Quadrillion Btu)					
Baseline	4.7	4.7	4.8	4.9	5.0
$20 Tax	4.3	3.8	3.9	4.1	3.1
80% Reduction	4.3	3.6	1.4	0.4	0.5
Natural Gas Consumption (Quadrillion Btu)					
Baseline	1.8	2.0	2.0	2.1	2.2
$20 Tax	1.9	1.9	1.9	1.9	1.8
80% Reduction	1.9	1.9	1.9	1.8	1.8
Gasoline (Billions of Gallons)					
Baseline	10	9.4	9.0	8.8	8.6
$20 Tax	10	9.1	8.6	8.4	8.0
80% Reduction	10	9.0	8.4	7.2	5.6

Regional Results for Upper Midwest

Electricity Sector Impacts

	2013	**2023**	**2033**	**2043**	**2053**
Coal Generator Retirements (GW)					
$20 Tax	2.1	16	17	17	33
80% Reduction	2.1	19	45	66	66
Total Electricity Demand (% Change from Baseline)					
$20 Tax	-2.5%	-7.6%	-11%	-14%	-12%
80% Reduction	-2.6%	-11%	-18%	-29%	-26%

Labor Impacts

	2013	**2023**	**2033**	**2043**	**2053**
Wage Rate (% Change from Baseline)					
$20 Tax	-1.7%	-1.6%	-1.6%	-1.9%	-1.9%
80% Reduction	-1.6%	-2.0%	-2.9%	-6.2%	-9.5%
Job-Equivalents (Change from Baseline in Thousands)					
$20 Tax	-210	-230	-270	-350	-390
80% Reduction	-200	-290	-470	-1,170	-1,960

Welfare

	2013
Welfare (% Change from Baseline)	
$20 Tax	-0.58%
80% Reduction	-1.16%

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