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To this end, the Joint Program brings together an interdisciplinary group from two established MIT research centers: the **Center for Global Change Science (CGCS)** and the **Center for Energy and Environmental Policy Research (CEEPR)**. These two centers—along with collaborators from the Marine Biology Laboratory (MBL) at Woods Hole and short- and long-term visitors—provide the united vision needed to solve global challenges.

At the heart of much of the program's work lies MIT's Integrated Global System Model. Through this integrated model, the program seeks to discover new interactions among natural and human climate system components; objectively assess uncertainty in economic and climate projections; critically and quantitatively analyze environmental management and policy proposals; understand complex connections among the many forces that will shape our future; and improve methods to model, monitor and verify greenhouse gas emissions and climatic impacts.

This reprint is intended to communicate research results and improve public understanding of global environment and energy challenges, thereby contributing to informed debate about climate change and the economic and social implications of policy alternatives.

—Ronald G. Prinn and John M. Reilly,
Joint Program Co-Directors

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The Revenue Implications of a Carbon Tax

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Abstract: A primary reason for implementing a carbon or greenhouse gas tax is to reduce emissions, but in recent years there has been increased interest in a carbon tax's revenue potential. This revenue could be used for federal deficit reduction, to help finance tax reform, support new spending priorities such as infrastructure spending, offset the burden of the tax on households, or other purposes. With an environmental goal to reduce emissions to very low levels, programs that become dependent on the revenue may come up short when and if carbon revenue begins to decline. To date, the revenue potential of a carbon tax has not been studied in detail. This study focuses on how much carbon tax revenue can be collected and whether there is a carbon "Laffer Curve" relationship, with a point where revenue begins to decline. We employ the MIT U.S. Regional Energy Policy (USREP) model, a dynamic computable general equilibrium model for the U.S. economy, for the numerical investigation of this question. We consider scenarios with different carbon prices and emissions reductions goals to explore how they may affect whether and at what tax rate revenues peak. We find that a sufficiently high tax rate would induce a revenue peak between now and 2050. For the scenarios we study, however, we find that carbon tax revenue is a dependable source of revenue to finance federal fiscal initiatives over a thirty-year period at the minimum. We also explore how the cost of low-carbon technology and existing energy policies interact with tax rates and revenues. Our results indicate that lower costs of abatement technology make emissions more responsive to the tax rate, and removing regulations on renewables and personal transportation results in more carbon tax revenues. Our results also show that either lowering technology costs or removing existing policies would reduce the welfare cost of a carbon policy with specific reduction goals, with a larger offsetting gain from eliminating distortions associated with existing policies.

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1. Introduction

The United States is living through a period of considerable climate policy uncertainty. While the Trump Administration announced that the United States would withdraw from the Paris Agreement and has moved forward with plans to roll back the Clean Power Plan and other climate-related regulations, the general public appears increasingly concerned about the issue. According to one recent poll, voters feel the Trump Administration should not remove specific regulations to combat climate change.[1] Another poll focused specifically on Trump voters finds that nearly two-thirds of these voters support regulating or taxing greenhouse gas emissions.[2]

Meanwhile, the Republican agenda calls a major overhaul of income taxes including rate cuts and the Trump Administration has discussed a major infrastructure spending package. A major obstacle to any of these initiatives is their potential impact on the federal budget deficit. Recently, a group associated with the Republican oriented American Action Forum proposed a "20/20" plan to combine a carbon tax starting at $20 a ton and growing at an annual 4 percent real rate with a cut in the corporate income tax rate to 20 percent. Coming from another direction, a group of senior Republican leaders including former Secretaries of State George Shultz and James Baker, former Secretary of the Treasury Henry Paulson as well as former heads of the Council of Economic Advisers, Martin Feldstein and N. Gregory Mankiw, have proposed a $40 per ton carbon tax rising over time with revenues rebated to U.S. families through a monthly carbon dividend.[3]

Of course, a primary reason for implementing a carbon or greenhouse gas tax is to reduce emissions (Metcalf, 2009). The policy initiatives above, however, speak to the increased interest in a carbon tax's revenue potential. The revenue could be used for federal deficit reduction, to help finance tax reform, support new spending priorities such as infrastructure spending or, as proposed above, simply returned to households. Carbon revenue used for new initiatives might net out some funding for temporary transitional assistance to workers in industries particularly affected by the carbon tax or to address concerns about impacts on low-income households. But even after some set-aside, there likely would be considerable revenue for other uses in the federal budget.

Given the environmental goal of ultimately reducing emissions to very low levels, programs that become dependent on the revenue may face funding challenges when and if carbon revenue begins to decline. To date, the revenue potential of a carbon tax has not been studied in detail. This study focuses on how much carbon tax revenue can be collected and at what point the tax revenue peaks and starts to decline. In other words, we explore the carbon version of the "Laffer Curve" (Wanniski, 1978) relationship that postulates a trade-off between the tax rate and revenue. We examine the gross revenue from the carbon tax alone, the net change in tax collection for the Federal tax system as a whole accounting for reduction in other taxes, and the impact on State tax collections. The net impact on tax collection takes into account changes in income and payroll tax revenue due to reduced economic activity in response to implementation of carbon taxes. Any legislation would face an evaluation of the revenue impacts by the Joint Committee on Taxation (JCT). Under budgeting rules that go back to the Congressional Budget Act of 1974 (PL 93-344), JCT was tasked to provide revenue estimates for all tax legislation; these estimates are the official estimates used for legislative purposes and in subsequent balanced budget legislation and other budgetary control legislation.[4] As part of its revenue estimating process, the JCT only considers net revenue increases from a tax after taking account of a tax change's impact on other taxes. For excise taxes, JCT assumes a set offset percentage to income and payroll taxes for each year of the present law baseline.[5] JCT does not consider impacts on state tax revenue, which we calculate endogenously in our model. While not part of the Federal offset calculation, this impact may be of interest to States.

We employ the MIT U.S. Regional Energy Policy (USREP) model (Rausch *et al.*, 2010a), a dynamic computable general equilibrium model for the U.S. economy, for

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[1] Quinnipiac poll taken March 30 – April 3, 2017 available at https://poll.qu.edu/national/release-detail?ReleaseID=2449.

[2] Leiserowitz, A., Maibach, E., Roser-Renouf, C., Cutler, M., & Rosenthal, S. (2017). *Trump Voters & Global Warming*. Yale University and George Mason University. New Haven, CT: Yale Program on Climate Change Communication, available at http://climatecommunication.yale.edu/publications/trump-voters-global-warming/ (accessed on April 12, 2017).

[3] The American Action Forum 20/20 plan is described at https://www.americanactionforum.org/research/tax-reform-initiative-group-briefing-book/. The tax and dividend plan is described at https://www.clcouncil.org/.

[4] JCT's role in the budget process is described at https://www.jct.gov/publications.html?func=startdown&id=1174. Also see its description of its revenue estimating process at https://www.jct.gov/publications.html?func=startdown&id=4969. JCT's revenue estimating procedure and revenue scoring are not CGE model outcomes. While the estimates assume a wide variety of behavioral responses, they generally assume that the size of the economy (GNP) is unchanged. Among other things, this means that total labor supply, employment, and investment are held constant as described in JCT's revenue estimating process document. Our offset estimates will differ from JCT's estimates in part because of this assumption on GNP.

[5] The rationale and procedure for the offset is described in Joint Committee on Taxation Staff (2011).

the numerical investigation of the tax revenue questions. We consider scenarios with different carbon prices and emissions reductions goals to explore how they may affect whether and at what tax rate revenues begin to decline. We find that revenue peaks and begins to decline at the higher tax rates we consider. However, even in these scenarios, the revenue declines are relatively small, and thus we conclude that a carbon tax is likely a dependable source of revenue to finance federal fiscal initiatives over at least the thirty-year horizon of our study for policy targets that have been proposed by various groups.

When exploring how the cost of low-carbon technology and existing policies interact with tax rate and tax revenues, our preliminary results suggest that a lower cost of abatement technology makes emissions more responsive to the tax rate and reduces the revenue potential for any given target emissions reduction. Removing regulations on renewables and personal transportation, on the other hand, results in more carbon tax revenues. Our results also show that either lower technology costs or removal of the existing policies would reduce the negative welfare impact of a carbon policy with specific reduction goals, with a larger offsetting gain from eliminating distortions associated with the existing policies.

Our paper proceeds as follows. Section 2 describes the USREP model that we use for the analysis. We then discuss the various scenarios we consider in Section 3. In Section 4 we present the results and draw some policy implications. We conclude with thoughts for further analysis.

2. The Model

2.1 Data

The USREP model is built on an energy-economic dataset of the U.S. economy, called IMPLAN (IMPLAN, 2008). For the purpose of energy and environmental policy study, we improve the input-output dataset (Lindall *et al.* 2006) at the state-level prepared by IMPLAN by replacing its energy accounts with physical energy quantities and energy prices from Energy Information Administration State Energy Data System (EIA-SEDS, 2009) for the same benchmark year 2006. The final dataset is rebalanced using constrained least-squares optimization techniques for a consistent representation of the economy (Rausch and Rutherford, 2008). Additional data sources are used to improve the model parameterization (**Table 1**).

We aggregate the dataset to 12 U.S. regions, 11 sectors, and 9 households grouped by annual income classes. The regional definition characterizes separate electricity interconnects, and captures some of the diversity among states in consumption and production of energy. The 509 commodities are aggregated to five energy sectors and six non-energy sectors. The energy sectors include coal (COL), natural gas (GAS), crude oil (CRU), refined oil (OIL) and electricity (ELE). The non-energy sectors include energy-intensive industries (EIS), agriculture (AGR), commercial transportation (TRN), personal transportation (HHTRN), services (SRV) and all other goods (OTH). Primary factors include labor, capital, and land, as well as depletable fossil fuels and wind and biomass supply as renewable resources. Households across income classes differ in terms of income sources and expenditure patterns.

Our dataset permits calculation of existing tax rates comprised of sector and region-specific ad-valorem output taxes, payroll taxes and corporate income taxes. The dataset has been augmented by incorporating regional tax data for 2006 (available at http://www.nber.org/taxsim)

Table 1: USREP data sources

Data and Parameters	Source
Social Accounting Matrices	Minnesota IMPLAN Group (2008)
Physical energy flows and energy prices	Energy Information Administration - State Energy Data System (EIA-SEDS, 2009)
Fossil fuel reserves and biomass supply	U.S. Geological Survey (USGS, 2009) U.S. Department of Energy (DOE, 2009) Dyni (2006) Oakridge National Laboratories (2009)
High-resolution wind data	National Renewable Eenrgy Laboratory - Wind Integration Datasets (NREL, 2010)
Non-CO_2 GHG Inventories and endogenous costing	U.S. Environmental Protection Agency (EPA, 2009) Hyman *et al.* (2002)
Marginal personal income tax rates	NBER's TAXSIM model (Feenberg and Coutts, 1993)
Trade elasticities	The GTAP 7 Data Base (Narayana and Walmsley, 2008) and own calculation Own calculation
Energy demand and supply elasticities	MIT EPPA model (Paltsev *et al.*, 2005; Chen *et al.*, 2014)
Passenger vehicle transportation	U.S. Department of Transportation (2009)

from the NBER TAXSIM model (Feenberg and Coutts, 1993) to represent marginal personal income tax rates by region and income class. Using marginal tax rates is important both in terms of better representing the deadweight loss associated with a progressive income tax structure and for estimating the impacts on revenue from these sources when activity levels (tax base for each) are affected by the carbon tax. We approximate the U.S. progressive income tax with an income-specific linear income tax by setting a marginal tax rate for each income class to match marginal tax rates from the TAXSIM model and then set the intercept so that average tax rates match IMPLAN data at the regional/income class level. For projecting forward, we adjusted the intercept so that the effective revenue government raised through taxes matches AEO 2017 projections (EIA, 2017).

Energy supply is regionalized by incorporating data for regional crude oil and natural gas reserves from U.S. Department of Energy (DOE, 2009), coal reserves estimated by the U.S. Geological Survey (USGS, 2009), and shale oil (Dyni, 2006). Our approach to characterizing wind resource and incorporating electricity generation from wind in the model based on data from the National Renewable Energy Laboratory (NREL, 2010) is described in detail in Rausch and Karplus (2014). We derive regional supply curves for biomass from data from Oak Ridge National Laboratories (2009) that describes quantity and price pairs for biomass supply for each state.

2.2 Model Overview

Our modeling framework draws on a multi-commodity, multi-region, multi-household numerical general equilibrium model of the U.S. economy. The model used a recursive-dynamic solution approach implying that economic agents have myopic expectations, basing their decisions on current period information.

In each industry, gross output is produced using inputs of labor, capital, energy and intermediate material goods. Primary energy production sectors (crude oil, shale oil, coal, natural gas) use depletable natural resources (crude oil, coal, and natural gas). The model also includes primary energy production sectors that use renewable, non-depletable resources (wind and biomass). Agriculture and biomass production uses land.

We employ constant-elasticity-of-substitution (CES) functions to characterize how production technologies respond to changes in the relative prices of inputs. All industries are characterized by constant returns to scale (CRS). Limited depletable and renewable resource inputs to primary energy production sectors give these sectors upward sloping supply, even though the basic production structure is CRS.

Consumption, labor supply, and savings result from the decisions of representative households by income class in each region maximizing utility subject to a budget constraint. The IMPLAN data include capital income by region and income class, but the dataset does not source the ownership of depletable and renewable resources. Hence, regional resource endowments are distributed to households in proportion to capital income. Given input prices gross of taxes, firms maximize profits subject to technology constraints. Firms operate in perfectly competitive markets and maximize their profit by selling their products at a price equal to marginal costs. In each region, a single government entity approximates government activities at all levels—federal, state, and local. Government consumption is paid for with income from tax revenue net of inter-institutional transfers (e.g., transfers to households). To ensure a comparable welfare comparison across policy scenarios, government consumption is held at the constant level as in the baseline.

Advanced energy supply options are specified as “backstop” technologies that enter endogenously when they become economically competitive with existing technologies. Competitiveness of advanced technologies depends on the endogenously determined prices for all inputs, as those prices depend on depletion of resources, energy and environmental policies, and other forces driving economic growth. We adopt a top-down approach of representing technologies following Paltsev *et al.* (2005) where each technology can be described through a nested CES function. **Table 2** summarizes the advanced technology options. Eight technologies produce perfect substitutes for electricity. Three technologies produce perfect substitutes for conventional fossil fuels. Three technologies provide alternative personal vehicle transportation options.

We adopt a putty-clay approach where a fraction of previously installed capital becomes nonmalleable and frozen into the prevailing techniques of production. Vintaged production in a given industry that uses non-malleable capital is subject to a fixed-coefficient transformation process in which the factor intensities of capital, labor, intermediate inputs and energy by fuel type are set to be identical to those that prevailed in the period when the capital was installed. Each of the sector-specific vintages is tracked through time as a separate capital stock. This formulation captures the stickiness in substitution among production inputs when relative prices change. In other words, it means that the model exhibits different short-run and long-run response, with a more elastic response to energy price increases in the long-run driven by the gradual replacement of less energy efficient capital with more efficient capital over time.

Our framework incorporates a detailed representation of private passenger vehicle transport that allows projections of vehicle-miles traveled (VMT), fleet stock turn-

Table 2: USREP advanced technologies

Technology	Description
Electricity	
Biomass generation	Convert biomass into electricity
Wind / Solar	Intermittent wind/solar resources
Wind / gas backup	Intermittent wind generation with natural gas backup
Wind / biomass backup	Intermittent wind generation with biomass backup
Advanced gas	Natural gas combined cycle (NGCC)
Advanced gas / CCS	NGCC that captures 90% or more of the carbon emissions produced in electricity generation
Advanced coal / CCS	Advanced coal that captures 90% or more of the carbon emissions produced in electricity generation
Advanced nuclear	Next generation of nuclear power plants incorporating estimated costs of building new nuclear power plants in the future
Fossil Fuel	
Coal gasification	Converts coal into natural gas
Shale oil	Converts shale oil into crude oil
Biomass liquids	Converts biomass into refined oil
Personal Transport	
PHEV	Plug-In Hybrid Electric Vehicles
CNG	Compressed natural gas vehicles
EV	Electric vehicles

over, and fuel price-induced investment in fuel efficiency. This allows studies of policies such as the U.S. Corporate Average Fuel Economy (CAFE) standards that target improvements in vehicle fuel efficiency as the framework differentiates between newly purchased and pre-existing vehicle stocks in each period. Changes in overall vehicle-miles traveled as well as the fuel use and GHG emissions of new and pre-existing vehicles are tracked. More detailed description and discussion of the model features are available in Rausch *et al.* (2010a,b).

USREP is formulated as a mixed complementarity problem (MCP) (Mathiesen, 1985; Rutherford, 1995), coded in MPSGE (Rutherford, 1999), and solved by PATH solver (Dirkse and Ferris, 1995).

3. Scenarios

We updated the USREP baseline since the most recent published work (Rausch and Reilly, 2015), calibrating labor productivity to match GDP forecasts to the Annual Energy Outlook (AEO) of the Energy Information Administration (EIA, 2017). The update includes incorporating the CAFE standards for personal vehicle transportation into the baseline. Also represented in the baseline scenario are regional renewable portfolio standards (RPS) to reflect the various RPS programs in different states based on EIA AEO assessment (EIA, 2017).

We designed a set of carbon policy scenarios that represent a variety of tax rates and emissions targets that have received policy attention. These include (1) a *$40@4%* case with a carbon tax starting at $40 per ton of CO_2 and rising at 4 percent real from 2020 to 2050; and (2) a *26/80 Reduction* case where a carbon tax is set to achieve 26 percent reduction in emissions relative to 2005 by 2025 as proposed in the U.S. Intended Nationally Determined Contribution (INDC) under the Paris Agreement, and an 80 percent reduction in emissions by 2050, an aspirational target analyzed in the United States Mid-Century Strategy (MCS) for Deep Decarbonization building on the 2009 G8 meeting in L'Aquila that called for an 80 percent reduction in emissions by developed countries by 2050.[6] The emission targets in the intermediate years are linearly interpolated.

To further explore how tax rate and tax revenue are affected by the cost of low-carbon technology and existing policies, we develop two additional scenarios, both achieving the same carbon emission reductions as in the *26/80 Reduction* case. The *26/80 Low Cost* scenario assumes a lower cost of low-carbon technologies, as the cost of these backstop technologies are highly uncertain (IEA, 2015) but could fall in the future with technolo-

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[6] The Mid-Century Strategy (MCS) for Deep Decarbonization found it is technically feasible to achieve an 80% greenhouse gas reduction below 2005 levels by 2050 in the U.S. (https://unfccc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf). The L'Aquila Chairs Summary is available at http://ec.europa.eu/economy_finance/publications/publication15572_en.pdf.

gy advance. For our purposes of focusing on tax revenue collection, it does not matter which electricity option has a lower cost. For simplicity, we lowered the cost markup of advanced nuclear generation by 20%. We also assumed for this case further breakthroughs in electric vehicles (EV) for personal transportation, lowering their cost by 20%. The *26/80 No CAFE/RPS* scenario removes the existing CAFE and RPS targets from the baseline, consistent with the new Administration's rolling back of Obama era climate policies. We also model the elimination of state-level RPS programs in order to measure the welfare cost of these sector-specific strategies.

To maintain revenue neutrality, an endogenously calculated portion of the carbon tax revenue is reserved to replace any reduction in other tax collections brought about by the carbon tax and the rest of the revenue is distributed lump-sum to the households. In the current study, we assume that the revenue returned to the households is not taxed.[7] If the revenue were used to cut other taxes, that would reduce their distortionary effects and hence also have impacts on overall revenue. These effects are second-order—here our interest is in providing a first-order estimate of gross and net carbon tax revenue and how it changes with the tax rate. **Table 3** provides a summary of these scenarios.

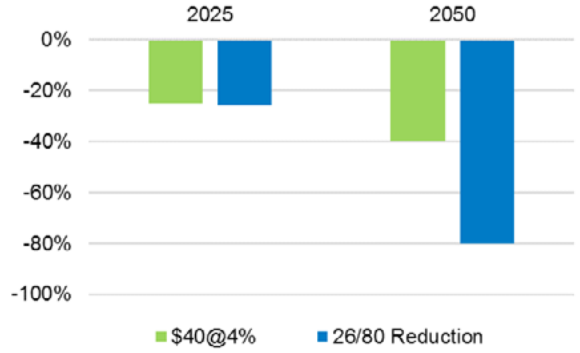

Figure 1: Emissions reductions (% change from the baseline)

4. Results

4.1 Emissions Reductions and Carbon Prices

The *26/80 Reduction*, *26/80 Low Cost* and *26/80 No CAFE/RPS* by design cut the emissions by the same amount from the baseline. **Figure 1** compares the emissions reductions in the *$40@4%* and *26/80 Reduction* cases relative to the 2005 level of 5982 $MMTCO_2$. Both cases result in about the same reductions by 2025. By 2050, the *$40@4%* case would cut 40% emissions relative to 2005, half the emission reductions achieved in the 26/80 cases.

Figure 2 shows taxes in each of the cases. The *$40@4%* case starts with a $40/tCO_2$ in 2020 growing to $130/tCO_2$ in 2050. The carbon tax rates needed to achieve the various 26/80 scenarios are endogenously determined. The *26/80 Reduction* case requires 17% emission reductions by 2020 relative to 2005 and so starts with a carbon price of $32/tCO_2$ in 2020 that rises to $55/tCO_2$ in 2025 and then to $520/tCO_2$ by 2050. In the *26/80 Low Cost* case, lowering the markup on advanced nuclear and EV makes both backstop technologies more economically competitive. It reduces the cost of decarbonization in the electricity and personal transportation sector beginning in 2030 when these technologies first become competitive at these lower costs. As a result, the needed tax rate in

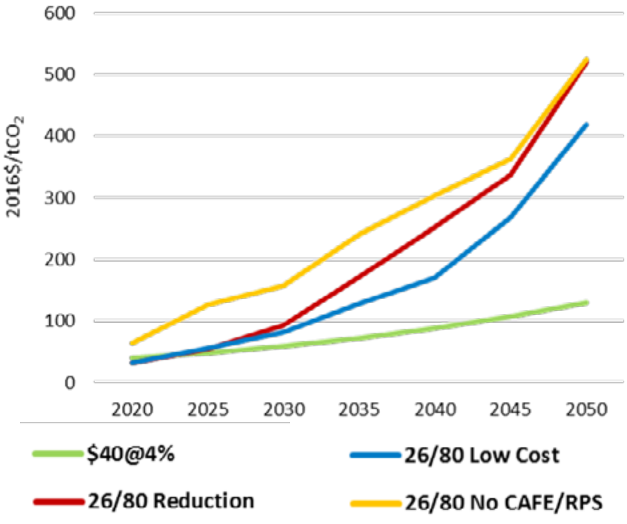

Figure 2: Carbon prices (2016$/$tCO_2$)

Table 3: Scenarios

Scenario Label	Policy Description
Baseline	Existing CAFE & Renewable targets
$40@4%	Carbon tax starts at $40 in 2020, rising 4% annually
26/80 Reduction	Carbon tax to reduce emissions 17% by 2020, 26% by 2025, and 80% by 2050, relative to 2005
26/80 Low Cost	*26/80 Reduction* + low cost electric vehicles + low cost low-carbon electricity
26/80 No CAFE/RPS	*26/80 Reduction* + removing CAFE & Renewable targets

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[7] Making the carbon tax distribution taxable would enhance the progressivity of the rebate given the U.S. progressive tax rate structure and would decrease the revenue loss in other taxes.

2030 is about $10 lower than in the *26/80 Reduction* case, with this difference growing to about $100 less in 2050.

The *26/80 No CAFE/RPS* case has higher carbon prices than the *26/80 Reduction* case. Removing CAFE in personal transportation and RPS in the electricity sector requires higher carbon prices through 2045, starting at \$64/tCO$_2$ in 2020 (\$32 above *26/80 Reduction*) and rising to \$126/tCO$_2$ by 2025 (\$71 above *26/80 Reduction*) with the difference diminishing after that and disappearing by 2050. Tax rates are higher because, in effect, we have replaced an implicit tax imposed through the regulations with an explicit tax for the electricity and transportation sector. The RPS and CAFE programs are still in effect under the high carbon prices in the *26/80 Reduction* case.[8] That is, the requirements under the regulations would only be partially met given the high tax rates required to achieve an 80 percent reduction by 2050. Completely removing RPS and CAFE would drive up carbon prices. Higher carbon prices, on the other hand, provide incentive to adopt fuel-efficient technologies for all sectors. The accumulation of more efficient capital stock in turn reduces carbon prices in the later periods for the same economy-wide emissions reduction. These two forces work in opposite direction, and by pure conincidence, bring the carbon prices in the two cases together by 2050.

4.2 Electricity Generation and Prices

A carbon price changes the cost competitiveness among generation technologies, making fossil based generation relatively more expensive than low-carbon or zero-carbon technologies, thus creating the incentive to deploy more low-carbon and zero-carbon technologies to minimize the cost of electricity production. **Figure 3** shows the changes in generation profile. At a lower level of carbon prices in the *\$40@4%* case, coal-fired generation is displaced with gas-fired and nuclear. In the *26/80 Reduction case*, advanced nuclear enters in 2030 and expands quickly to substitute for conventional fossil-fired generation. With a lower markup on advanced nuclear in *26/80 Low Cost* case, more advanced nuclear is deployed. Removing RPS programs eliminates the implicit subsidy to renewables and implicit tax on non-renewable generation sources. Compared to the *26/80 Reduction* case, generation from biomass, wind, and solar is displaced by fossil and nuclear in early periods before 2030 when advanced nuclear becomes commercially available. Post 2030, advanced nuclear penetrates at a much faster rate. By 2050, generation from advanced nuclear is one-third higher in the *26/80 No CAFE/RPS* scenario than in the *26/80 Reduction* case. With different cost assumptions, or limits on nuclear expansion because of safety concerns, a different mix of technologies would likely exist, with a different cost structure (see **Figure 4**).

Figure 5 shows how policy affects the cost of generation. The difference between the *\$40@4%* and *26/80 Reduction* case are in line with the difference in carbon prices. Among the 26/80 cases, the case with lower cost of advanced nuclear brings down the cost of generation by 23 percent starting in 2030 when advanced nuclear begins to penetrate. Moreover, lower carbon prices in the *26/80 Low Cost* case further reduce the cost increase from the baseline. Removing RPS starts to show an immediate impact starting in 2020, with only a 3% increase in generation cost in 2020 in comparison to a 4% increase in

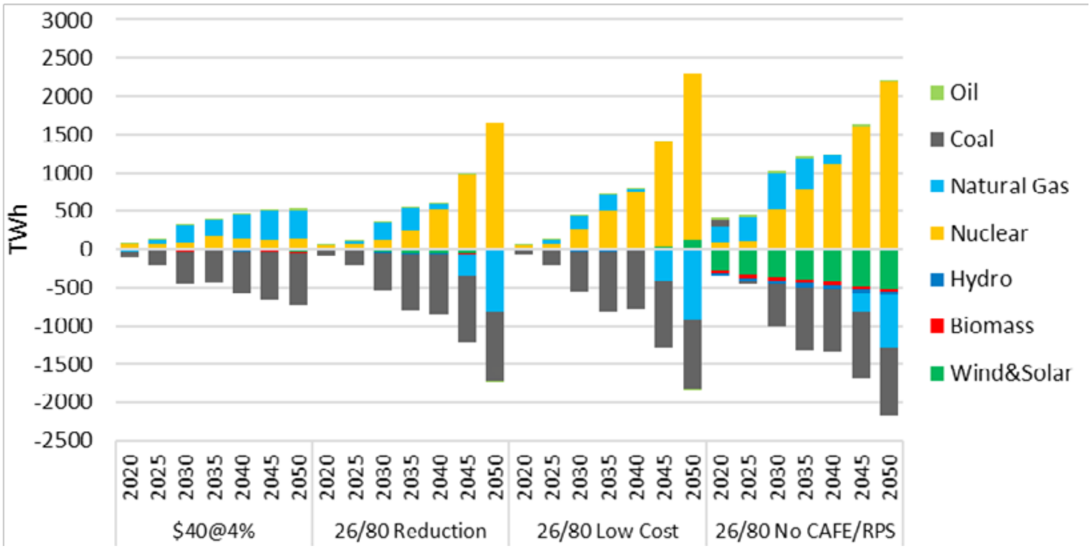

Figure 3: Electricity generation (change from the baseline, TWh)

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[8] We discuss the welfare implication in Section 4.5.

the *26/80 Reduction* scenario. As time goes on, the generation cost increase in the *26/80 No CAFE/RPS* case is shown to be less than both the *26/80 Reduction* and *26/80 Low Cost* case, despite higher carbon prices throughout the horizon. This result indicates that a carbon tax is a more cost-effective way to reduce emissions than through technology mandates such as RPS requirements.

4.3 Tax Revenue

As noted at the outset, a carbon tax provides revenue that could finance any number of government initiatives. But policy makers might be hesitant to turn to carbon taxes if they felt that having a stringent emission reduction target would lead to revenue shortfalls quickly. We investigate that issue now, looking first at carbon tax revenue alone (ignoring changes in other tax revenues). Overall, we find that carbon tax revenue does not peak in the *$40@4%* scenario over our 2020–2050 time horizon, and, while revenue exhibits peaks in the other scenarios, the decline of the revenue after the peak is relatively small in all cases (see **Figure 6**).

The *$40@4%* case raises the least revenue of all the cases (except in the 2020 when the *26/80 Low Cost* and *26/80 Reduction* require relatively low carbon prices). The *26/80 Low Cost* case raises slightly more than the *$40@4%* case and not as much revenue as the *26/80 Reduction* case. Conversely, the *26/80 No CAFE/RPS* case raises significantly more revenue than the *26/80 Reduction* case, especially in earlier years (i.e., through 2035). The *26/80 Reduction* and the *26/80 No CAFE/RPS* cases show a revenue peak. Revenue peaks in 2040 for the *26/80 Reduction* case, and in 2035 for the *26/80 No CAFE/RPS* case. The decline in revenue from its peak values in the *26/80 Reduction* case is 2% by the end of our study horizon (2050). The greatest decline (18%) is in the *26/80 No CAFE/RPS* but even with that decline revenue in 2050 is as high or higher than any of the other cases.

Overall the results show, first, the possibility of a peak in carbon tax revenue with very stringent climate policy targets; second, relatively modest declines in revenue when there is a peak, at least through the 2050 horizon of our study, and, third, technology cost and existing regulatory programs can strongly affect revenues as well as the timing of the peak.

We next turn our attention to net revenue raised from the carbon tax, taking into account reductions in revenue from other taxes. Such reductions come about because a carbon tax raises the cost of production for firms, lowers final demand, and demand for factors of production (e.g., capital and labor). This, in turn, leads to an erosion of payroll and income tax revenue. For budget scoring purposes, the Joint Committee on Taxation (JCT) employs an offset rule as described above that reduces the amount of an excise tax like a carbon tax that may be used for budgetary purposes.[9] Rather than use the JCT offset rule, USREP endogenously calculates changes in all sources of income and demands and provides consistent estimates of the changes in tax revenue from all sources. As we show below, our calculated offset is close to the JCT offset at low to moderate carbon tax rates. At higher rates, the official offset percentage appears to be lower than the actual offset.[10]

Figure 4 shows the changes in tax revenue by source as well as net Federal tax revenue in all four cases. The *$40@4%* case raises net Federal tax revenue from about $145 billion in 2020 growing to about $370 billion by 2050.[11] Compared to the *$40@4%* case, the net Federal tax revenue stream does not increase monotonically and peaks in 2040 for the *26/80 Reduction* and the *26/80 No CAFE/RPS* scenarios and in 2045 in the *26/80 Low Cost* scenario. As the carbon tax rate grows over time, the revenue change suggests a Laffer Curve relation between the carbon tax rate and the resulting revenue. Similar to the analysis of the carbon tax revenue in isolation, net tax revenue exhibits a similar Laffer Curve pattern and the shape of the curve varies depending on the technology cost assumption and existing policies.

The USREP model has a single government entity representing both Federal, State, and Local governments collecting personal and corporate income tax, payroll tax and other taxes. To break out the Federal tax revenue, we applied shares calculated based on Federal, State and Local government revenue for each tax category.[12] Our calculations are based on historic tax collections, where 80% of personal income tax, 87% of corporate income tax and 100% of payroll tax are allocated to Federal government. For all other taxes, 84% of the revenue is collected by State and Local governments. To calculate an offset, we add up the change in Federal revenue from personal and corporate income tax, payroll tax and excise tax. We then divide the total revenue from these taxes by the carbon tax

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[9] The annual offset percentage is between 25 and 26 percent for 2016–2026. See JCX-7-16, *New Income And Payroll Tax Offsets To Changes In Excise Tax Revenues For 2016-2026*, available at https://www.jct.gov/publications.html?func=startdown&id=4869

[10] As noted above, one factor driving differences in offset rates is the constant GNP assumption in JCT's revenue estimating procedures. Below we use the JCT offset measure to calculate how much revenue can be rebated to households since the JCT rule would determine how much of the carbon tax revenue may be used for rebates.

[11] The *$40@4%* scenario results in monotonically increasing carbon tax and net Federal tax revenues without running into a peak. The *26/80 Low Cost* scenario does not have a peak in carbon tax revenue, but the net Federal tax revenue peaks in 2040.

[12] Federal, State and Local government revenue by source is available at http://www.taxpolicycenter.org/statistics/revenue-government-level

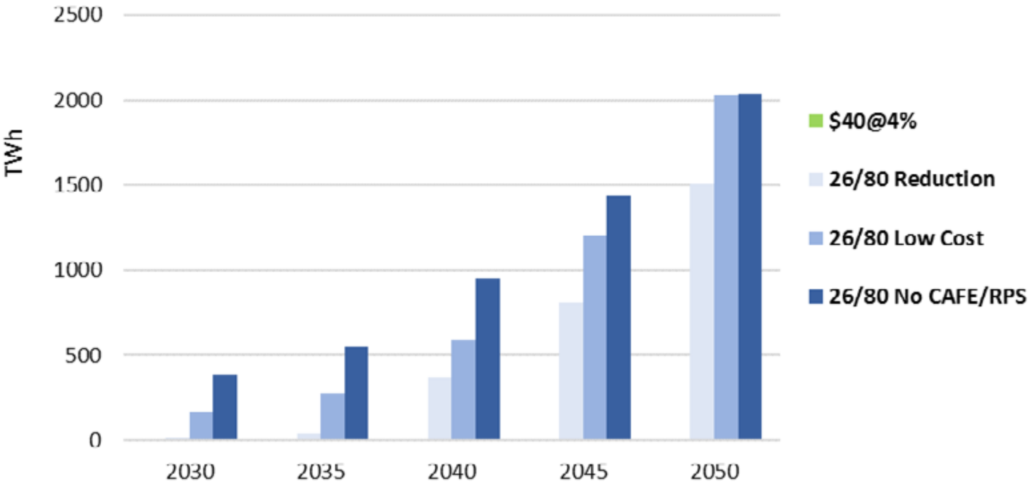

Figure 4: Advanced nuclear penetration (TWh). Note: in the *$40@4%* scenario, advanced nuclear generation appears only in 2050 and produces 5 TWh.

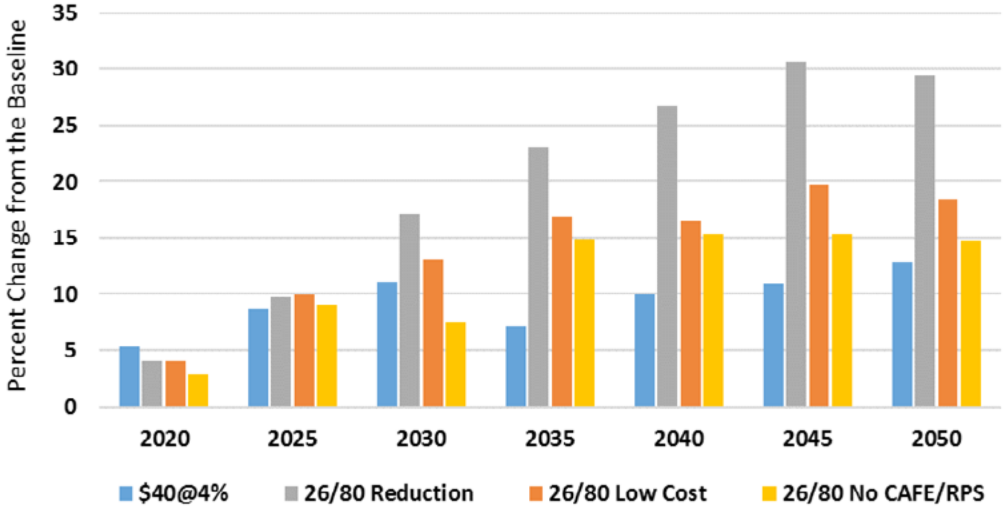

Figure 5: Cost of generation (percent change from the baseline)

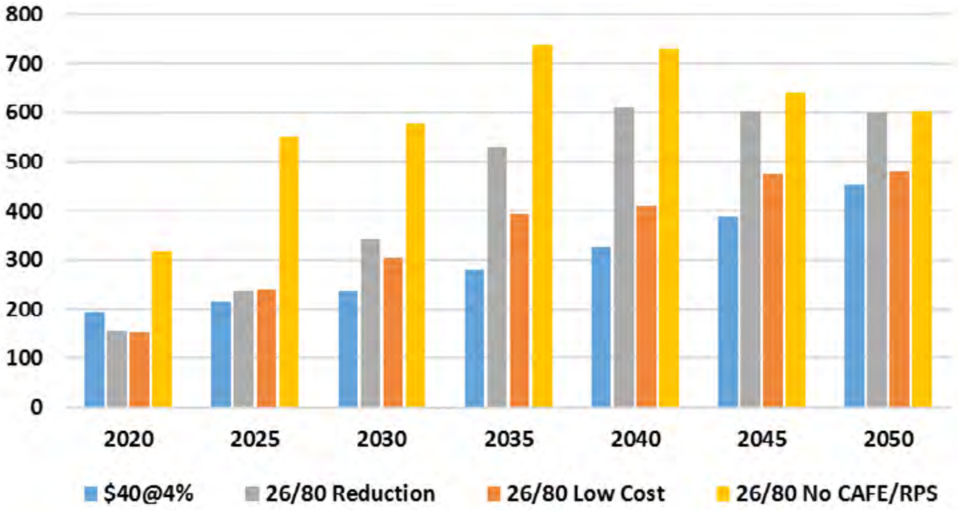

Figure 6: Carbon tax revenue in isolation (Billion 2016$)

revenue, as shown in the last column of **Table 4**.[13] Compared to the *26/80 Reduction* case, the *26/80 Low Cost* case requires a smaller carbon tax and so the offsetting losses from personal and corporate income, payroll and other taxes are smaller. Notably, the offsetting losses in the *26/80 No CAFE/RPS* are considerably smaller in general than the *26/80 Reduction* case. Despite higher carbon taxes that increase the cost of production, cheaper electricity prices due to the removal of RPS provides a countervailing effect that reduces the impact on production as well as tax collected from production. This shows an important interaction between pre-existing policies and the carbon tax.

The tax offset, represented by a percentage of carbon tax revenue that is set aside to replace lost federal tax revenue from income and payroll taxes, ranges from 19–27% in the *$40@4%* case, and 20–52% in the 26/80 cases. In contrast to our estimates, the Joint Committee on Taxation uses a tax offset of 25 percent (see Footnote 9). The changes in the tax offsets in different scenarios are roughly proportional to the changes in economic activities and welfare (discussed below) relative to the *Baseline*. These changes occur because a carbon tax raises the cost of production for firms, lowers final demand, and demand for factors of production, which leads to an erosion of non-carbon tax revenue. Removing distortions associated with regulations (RPS and CAFE) brings the offsets closer to the JCT estimate.

4.4 Revenue Rebate

The Climate Leadership Council that proposed the $40 tax proposed distributing revenue directly to individuals on an equal per capita basis.[14] We can estimate a car-

Table 4: Federal revenue offset calculated based on model results (Billion 2016$)

		Personal Income Tax	Corporate Income Tax	Payroll Tax	Excise Tax	Carbon Tax	Net Federal Revenue	Offset
$40@4%	2020	-26	-7	-14	-2	194	145	-25%
	2025	-27	-8	-18	-3	216	160	-26%
	2030	-30	-9	-22	-3	238	173	-27%
	2035	-30	-9	-23	-3	281	215	-24%
	2040	-32	-11	-27	-4	327	253	-23%
	2045	-35	-12	-31	-5	388	306	-21%
	2050	-36	-12	-32	-5	454	369	-19%
26/80 Reduction	2020	-20	-6	-11	-2	156	118	-25%
	2025	-30	-9	-20	-3	238	176	-26%
	2030	-48	-14	-33	-5	343	243	-29%
	2035	-75	-22	-57	-8	528	366	-31%
	2040	-83	-26	-73	-10	611	418	-32%
	2045	-96	-28	-89	-12	603	377	-37%
	2050	-136	-31	-126	-18	600	289	-52%
26/80 Low Cost	2020	-20	-6	-12	-2	154	115	-25%
	2025	-29	-9	-20	-3	240	179	-25%
	2030	-37	-10	-28	-4	305	225	-26%
	2035	-45	-12	-39	-5	393	292	-26%
	2040	-36	-11	-39	-4	411	321	-22%
	2045	-60	-15	-61	-8	476	333	-30%
	2050	-95	-19	-104	-13	481	251	-48%
26/80 No CAFE/RPS	2020	-37	-10	-19	-2	318	249	-21%
	2025	-72	-21	-38	-5	549	413	-25%
	2030	-76	-22	-46	-7	579	429	-26%
	2035	-97	-25	-64	-8	738	544	-26%
	2040	-87	-19	-58	-6	731	561	-23%
	2045	-80	-8	-39	-3	641	511	-20%
	2050	-111	1	-41	-3	602	447	-26%

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[13] Only Federal revenue is provided in Table 4. Note that state tax revenue is affected as well because carbon tax is collected at a Federal level, but state tax collections are reduced for the similar reasons that affect federal non-carbon taxes.

[14] Described at https://www.clcouncil.org/

Table 5: Revenue rebate (per person/year, Billion 2016$

	2020	2025	2030	2035	2040	2045	2050
$40@4%	435	462	483	580	664	787	927
26/80 Reduction	352	508	677	988	1,100	969	727
26/80 Low Cost	343	516	627	789	845	854	630
26/80 No CAFE/RPS	746	1,189	1,194	1,469	1,475	1,312	1,123

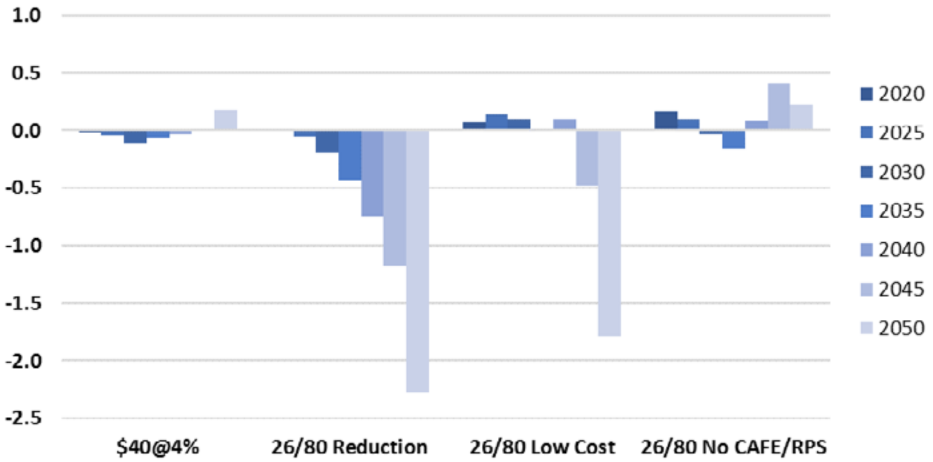

Figure 7: Welfare Change from the *Baseline* Scenario.

bon dividend that every U.S. person would be able to get from the government by dividing the net Federal tax revenue (from Table 4) by the U.S. population projected by U.S. Census Bureau (2014). The results are presented in **Table 5**. The carbon dividend (expressed in 2016$) grows from $343–746 in 2020 to $630–1123 in 2050 in different scenarios. This would be an annual dividend of the order of $2000–$4000 for a family of four.

4.5 Welfare

We next turn to the welfare implications of our various scenarios. We report change in welfare as equivalent variation which takes into account the change in consumption and leisure.[15] **Figure 7** shows the changes in welfare relative to the *Baseline* scenario (recall that CAFE and RPS are included in the *Baseline*). Welfare impacts in the *$40@4%* case are modest. This is not surprising given the relatively lower tax rate assumed in this case than carbon prices in the 26/80 scenarios. Welfare impacts in the *26/80 Reduction* case can run as high as 2.3% in 2050 when deep decarbonization is required. If the cost of green technologies comes down, welfare costs are lower by 0.5% relative to the *26/80 Reduction* case in 2050. Finally, removing CAFE and RPS improves the welfare impact relative to the *26/80 Reduction* scenario with immediate short-term gains from removing the RPS and larger long-term gains from removing both CAFE and RPS. This result strongly illustrates the economic benefit of allowing the market, when faced with a carbon tax, to choose the least cost low carbon technologies rather than relying on mandated technology policies.

As mentioned in Section 4.1, the carbon prices of the *26/80 Reduction* and the *26/80 No CAFE/RPS* case converge toward later periods. The welfare impacts of the two cases, however, are quite different. Although the carbon prices partially mute the RPS and CAFE requirements, there is substantial gain in welfare from removing those regulations. The gain is sufficiently large that it results in welfare improvement relative to the baseline for most of the model years. This suggests that the cost of RPS and CAFE programs are even greater than the carbon tax that are required to achieve 80% reduction by 2050.

5. Conclusion

This study focuses on how much carbon tax revenue can be collected and whether there is a carbon "Laffer Curve" relationship, where tax revenue peaks and begins to decline beyond a certain carbon tax rate. We employ the MIT U.S. Regional Energy Policy (USREP) model, a dynamic computable general equilibrium model for the U.S. economy, for the numerical investigation of this question. We consider scenarios with different carbon prices and emissions reductions goals to explore how that may

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[15] The changes in consumption relative to *Baseline* are mostly negative, but they display a similar relative pattern as the changes in equivalent variation based on consumption and leisure.

affect whether and at what tax rate revenues peak. We find that a sufficiently high tax rate would induce a revenue peak. For the scenarios we study, however, we find that carbon tax revenue is a dependable source of revenue to finance federal fiscal initiatives over a thirty-year period at the minimum because, even with a peak, the revenue decline is modest. When exploring how the cost of low-carbon technology and existing policies interact with tax rate and tax revenues, our results suggest that lower cost of abatement technology make emissions more responsive to the tax rate, and removing regulations on renewables and personal transportation results in more carbon tax revenues. Our results also show that either lowering technology cost or removing existing policies would reduce the negative welfare impact of a carbon policy with specific reduction goals, with a larger offsetting gain from eliminating distortions associated with existing policies such as RPS and CAFE. Finally, the welfare results point to the economic benefit of allowing the market, when faced with a carbon tax, to choose the least-cost low-carbon technologies rather than relying on mandates to achieve specific technology goals.

6. References

Chen Y.-H., S. Paltsev, J. Reilly, and J. Morris (2014): The MIT EPPA6 Model: Economic Growth, Energy Use, and Food Consumption. GTAP 17th Annual Conference on Global Economic Analysis (Dakar, Senegal, June 18). GTAP Resource 4443.

Dirkse, S. P. and Ferris M. C. (1995): The PATH solver: A non-monotone stabilization scheme for mixed complementarity problems. *Optimization Methods and Software*, **5**: 123–156.

DOE [U.S. Department of Energy] (2009): *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 1977 through 2007*. U.S. Department of Energy, Washington, DC. (http://www.eia.gov/naturalgas/crudeoilreserves).

Dyni, J.R. (2006): *Geology and Resources of Some World Oil-Shale Deposits*. Scientific Investigations Report 2005–5294. U.S. Department of the Interior, U.S. Geological Survey, Reston, VA.

EIA-SEDS [Energy Information Administration – State Energy Data System] (2009): *State Energy Data System*. Energy Information Administration, Washington, DC.

EIA [Energy Information Administration] (2017): *Annual Energy Outlook 2017*. Energy Information Administration, Washington, DC.

EPA [U.S. Environmental Protection Agency] (2009): *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2007.* U.S. EPA, Washington, DC. (https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2007).

Feenberg, D. and E. Coutts (1993): An Introduction to the TAXSIM Model. *Journal of Policy Analysis and Management* **12**(1): 189–194.

Hyman, R.C., J.M. Reilly, M.H. Babiker, A. Valpergue De Masin and H.D. Jacoby (2002): Modeling Non-CO_2 Greenhouse Gas Abatement. *Environmental Modeling and Assessment* **8**(3): 175–186.

IMPLAN (2008): *State-Level U.S. Data for 2006*. MIG Inc., Huntersville, NC. (http://support.implan.com).

IEA [International Energy Agency and Nuclear Energy Agency] (2015): *Projected Costs of Generating Electricity, 2015 Edition*. Organisation for Economic Co-operation and Development, France.

Joint Committee on Taxation (2011): *The Income and Payroll Tax Offset to Changes in Excise Tax Revenues*. JCX-59-11, JCT, Washington, DC.

Lindall, S., D. Olson and G. Alward (2006): Deriving Multi-Regional Models Using the IMPLAN National Trade Flows Model. *Journal of Regional Analysis & Policy* **36**(1): 76–83.

Mathiesen, L. (1985): Computation of Economic Equilibria by a Sequence of Linear Complementarity Problems. *Mathematical Programming Study* **23**: 144–162.

Metcalf, G.E. (2009): Designing a carbon tax to reduce U.S. greenhouse gas emissions. *Review of Environmental Economics & Policy* **3**: 63–83.

NREL [National Renewable Energy Laboratory] (2010): *Wind Integration Datasets*. National Renewable Energy Laboratory, Golden, CO.

Narayanan, G.B., and T.L. Walmsley (eds.) (2008): *Global Trade, Assistance, and Production: The GTAP 7 Data Base*. Global Trade Analysis Project (GTAP). Center for Global Trade Analysis, Purdue University, Lafayette, IN.

Oak Ridge National Laboratories (2009): *Estimated Annual Cumulative Biomass Resources Available by State and Price*. Oak Ridge National Laboratories, Oak Ridge, TN.

Paltsev, S., J.M. Reilly, H. Jacoby, R. Eckhaus, J. McFarland, M. Sarofim, M. Asadoorian and M. Babiker (2005): The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4. MIT JPSPGC *Report 125*, August, 73 p. (https://globalchange.mit.edu/publication/14578).

Rausch, S. and V. Karplus (2014): Markets versus Regulation: The Efficiency and Distributional Impacts of U.S. Climate Policy Proposals. *The Energy Journal* **35**(S1): 199–227.

Rausch, S., G.E. Metcalf, J.M. Reilly and S. Paltsev (2010a): Distributional Impacts of a U.S. Greenhouse Gas Policy: A General Equilibrium Analysis of Carbon Pricing (Chapter 3). In: *U.S. Energy Tax Policy*, Metcalf, Gilbert E. Editor, Cambridge University Press, Cambridge, MA, pp. 52–112.

Rausch, S., G.E. Metcalf, J.M. Reilly and S. Paltsev (2010b): Distributional Implications of Alternative U.S. Greenhouse Gas Control Measures. *The B.E. Journal of Economic Analysis and Policy* **10**(2) (http://dx.doi.org/10.2202/1935-1682.2537).

Rausch, S. and J.M. Reilly (2015): Carbon Taxes, Deficits, and Energy Policy Interactions. *National Tax Journal* **68**(1):157–178.

Rausch, S. and T.F. Rutherford (2008): *Tools for Building National Economic Models Using State-Level IMPLAN Social Accounts*. (http://www.mpsge.org/IMPLAN2006inGAMS/IMPLAN2006inGAMS.pdf).

Rutherford, T.F. (1995): Extension of GAMS for Complementarity Problems Arising in Applied Economics. *Journal of Economic Dynamics and Control* **19**(8): 1299–1324.

Rutherford, T.F. (1999): Applied General Equilibrium Modeling with MPSGE as a GAMS Subsystem: An Overview of the Modeling Framework and Syntax, *Computational Economics* **14**: 1–46.

U.S. Census Bureau (2014): *2014 National Population Projections Tables*. (https://www.census.gov/data/tables/2014/demo/popproj/2014-summary-tables.html).

U.S. Department of Transportation (2009): *Federal Highway Administration, 2009 National Household Travel Survey.* (http://nhts.ornl.gov).

USGS [U.S. Geological Survey] (2009): *USCOAL Coal Resources Database*. U.S. Department of the Interior, U.S. Geological Survey, Reston, VA. (https://energy.usgs.gov/Coal/AssessmentsandData/CoalDatabases.aspx).

Wanniski, J. (1978): Taxes, Revenues, and the Laffer Curve. *The Public Interest* **50**: 3–16.

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