The Economic, Fiscal, Emissions, and Demographic Implications from a Carbon Price Policy in Vermont

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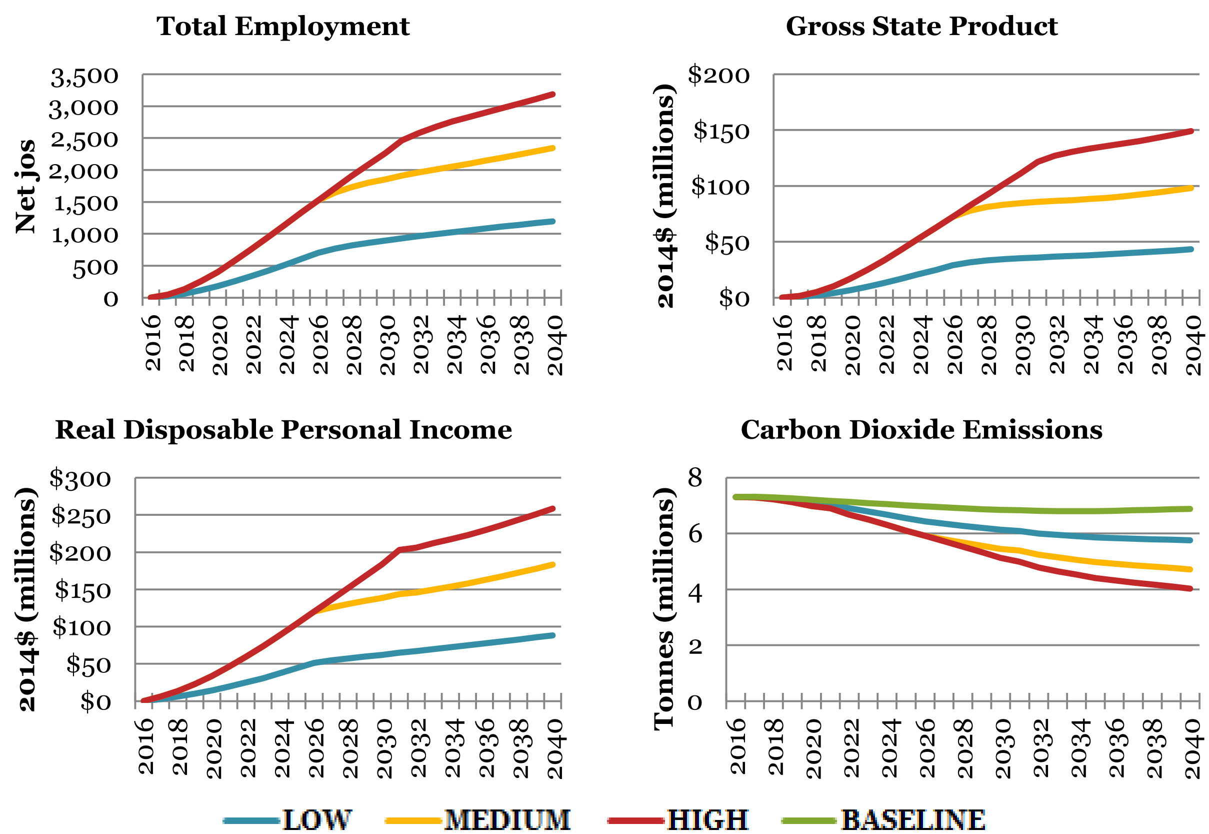
Thursday, November 13, 2014

Executive Summary

This study examines the potential impacts of a carbon price in Vermont on the state economy, household income, demographics, tax revenues, and carbon dioxide emissions. The Vermont Public Interest Research and Education Fund (VPIREF) engaged Regional Economic Models, Inc. (REMI) to perform this analysis using two models: the Carbon Tax Analysis Model (CTAM), which covers impacts to carbon emissions and tax revenues, and REMI PI+, a model of the economy including jobs, competitiveness, and growth. This white paper examines three potential price rates—those three cases are LOW (a tax peaking at $50 per metric ton of carbon dioxide), MEDIUM ($100), and HIGH ($150) as illustrated below. In addition, the simulations included a mixture of revenue recycling for the carbon funds. They involve direct payments or a higher personal exemption for households, extra rebates or tax credits for low-income households, cuts to corporate income taxes, rebates based on the share of state employment for nonprofits and the government, and 10% of the funding going towards state energy programs. This policy design for revenue recycling translates into at least 13% or 14% of total carbon revenues going to the lowest 20% of households. This ensures low-income families suffer no harm from a carbon price; the Congressional Budget Office (CBO) reported 11% to 12% of revenues would make the lowest quintile "whole" again despite changing energy prices. Energy investment programs include installation of cold climate heat pumps in homes using heating oil, electrification of cars, and hybridization of cars, incentives for solar, heating and process fuel efficiency, and weatherization of homes. The carbon pricing cases with the revenue options have a positive net impact on the Vermont economy, mostly because of reduced imports of fossil fuels from other states—and therefore more dollars staying within Vermont—and the labor-intensity businesses that expand with an increase in localized consumer spending. The impact for state emissions is significant, as well, reducing total carbon dioxide emitted from the Green Mountain State, in the HIGH case and in 2040, by as much as 40% from the baseline.



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Acknowledgments

For their support in making this report possible, we thank the Blittersdorf Family Foundation, the John Merck Fund, Mathew Rubin, and Barbarina Heyerdahl.

The author would also like to thank Ben Walsh from VPIREF and George Twigg from VEIC for their extensive comments and patience in drafting the document. From REMI, we would like to thank the copyediting work of Ali Zaidi, Andrew Tatro, and Rod Motamedi. We would also like to thank Jessica Langerman and Cathy Carruthers for their initial interest in state-level carbon pricing and in the support for the development of these methodologies.

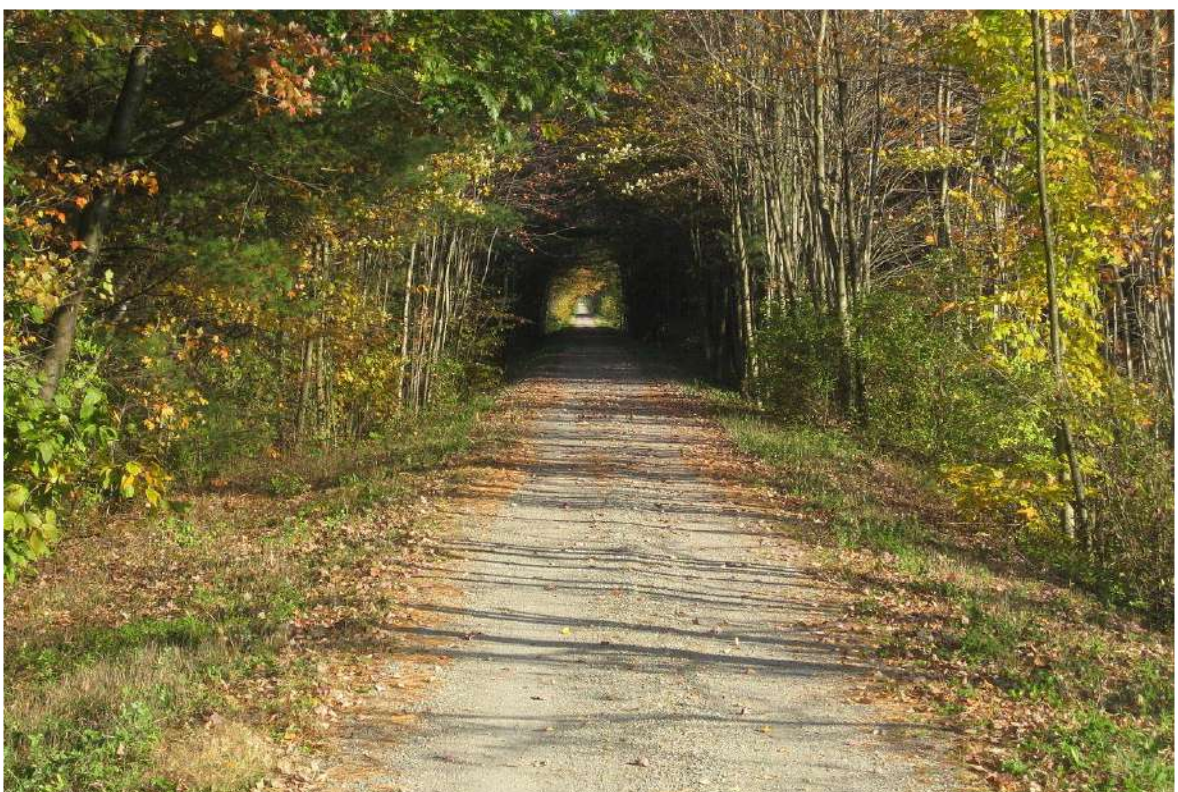
Introduction

In Vermont, as with any state, there are a complex series of interactions among the economy, the environment, energy, demographics, and the budget. This white paper holds these parallel to one another by examining a state-level carbon price in the Green Mountain State and its possible effects on the state economy, budget, and level of carbon emissions. A "carbon price," also known as a "carbon tax" or "carbon fee," is an excise tax leveled by some level of the government at a point in the energy supply-chain benchmarked to the release of carbon dioxide associated with the eventual combustion of the fuel. While other compounds related to local air quality or postulated impacts on world climate could be a part of this fee, this study concentrates on carbon dioxide emissions alone. Predominantly, this means a fee on the usage of fossil fuel resources such as natural gas, petroleum, and, in most cases, electricity generated from natural gas or coal at a power plant. Vermont, however, presents an interesting case regarding a carbon price in the electricity sector due to its participation in the Regional Greenhouse Gas Initiative (RGGI) program.[1] RGGI already applies a carbon price to the electrical sector in the six states of New England as well as New York. **This report considers electricity "covered" with RGGI and, thus, concentrates on the "uncovered" portions of the energy sector with liquid and gaseous fuels.** It assesses the "net" impact of such a policy once the revenues from the tax "recycle" back into the economy, as well.[2]

[1] RGGI places a price on carbon dioxide emissions from power generation through an auction system. Nine states in the Northeast currently participate, including Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. For more information, please see the RGGI homepage, <http://www.rggi.org/>

[2] All images courtesy of *Wikimedia*

The end goal of the carbon price is twofold. Foremost, it seeks to reduce emissions by inducing a price response away from carbon-intensive fossil fuels by consumers and towards conservation, efficiency, or alternatives. Secondly, it seeks to preserve the economic wellbeing of households and businesses by recycling the revenues from the carbon fee in a beneficial manner. There are numerous potential options for recycling the revenues. Many policy designs for carbon prices favor "revenue-neutrality" or the strict adherence to a $1 tax cut or rebate for every $1 in new revenues from the carbon price, but that is not the approach analyzed here. In order to increase the number of dollars available for efficiency and renewable programs, the Vermont setup under focus in this paper returns 90% of the revenues to the state economy through a series of rebates and tax cuts with the 10% allocated towards state energy outreach. With the 90% returned directly to households, businesses, and institutions, the choices here include rebates to taxpayers, rebates for low-income households, reducing the corporate income tax rates of for-profit enterprises in the state, and returning funds to institutions. Institutions include groups and organizations that would pay carbon prices during their operation yet would have little to no liability in state corporate income taxes. These would include nonprofits, local governments, and the Vermont state government itself. The 10% for programs go toward a mixture of credits for home and business solar installations, converting fossil heating equipment to heat pumps and other equipment, vehicular efficiency, and weatherization. Including these fiscal impacts from a fee, price, or tax invites the application of tools for assessing the competitiveness and economic impacts, which involves dynamic modeling. This report also considers a few of the distributional issues with carbon pricing and literature on the same.



For this report, the Vermont Public Interest Research Group (VPIREF) out of Montpelier, VT engaged with Regional Economic Models, Inc. (REMI) from Amherst, MA and Washington, DC to investigate these related economic, emissions, environmental, and demographic issues via the lens of modeling. This report relies on two tools: (1) the Carbon Tax Analysis Model (CTAM) and (2) REMI PI$^+$. CTAM is an open-source,[3] worksheet-based model of the emissions of a state that simultaneously provides a forecast of future carbon emissions, a potential delta under a carbon price, and a "static" revenue forecast for revenues from the price in every year at a rate of tax.[4] It draws its baseline assumptions and data from the Annual Energy Outlook (AEO)[5] prepared by the U.S. Energy Information Administration (EIA)[6] using a model called the National Energy Modeling System (NEMS).[7] The AEO projects energy consumption in a thermal unit (such as quadrillions of BTUs) and prices for those units at the New England-level out as far as 2040. CTAM breaks out Vermont and adjusts the forecast based on the price response to the carbon tax with exogenous parameters of price elasticity.[8] CTAM then integrates with PI$^+$ by providing changes in the cost of energy within a state and the quantity of revenue available for recycling. PI$^+$ is a proprietary economic and demographic model of sub-national units[9] of the United States. PI$^+$ includes variables for energy prices, taxes, and various other investments in the state economy involved in simulating the net impact of a carbon price with recycling on the Vermont economy. Highlight results from PI$^+$ include such metrics as total employment, gross state product (GSP),[10] and real personal income. CTAM and PI$^+$ integrate together for the purposes of analyzing carbon pricing at the state-level. This report is the latest in a series of like analyses for similar policy proposals in numerous states.

In the past year, REMI has completed a number of studies in the climate and energy sphere and their crossovers into economic, demographic, and fiscal impacts. There is also a pending study using PI$^+$ by the Northwest Economic Research Council (NERC)[11] at Portland State University (PSU)[12] on the impact of a carbon fee and rebates for the six regions of Oregon. Additionally, for perspective, while REMI and PI$^+$ analyze the economic and demographic implications of carbon fees, neither advocates nor endorses a particular course of action—REMI analyzes, reports, and

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[3] To directly download a copy of CTAM calibrated for the state of Washington in a Microsoft Excel file, please see, <http://daily.sightline.org/files/2011/08/Washington-State-Carbon-Tax-Analysis-Model.xls>

[4] The original creator of CTAM was Keibun Mori. For his original documentation, please see, "Washington State Carbon Tax," *Evans School of Public Affairs*, *University of Washington*, July 2011, <http://www.commerce.wa.gov/Documents/Washington-State-Carbon-Tax.pdf>

[5] The AEO data is online, please see, <http://www.eia.gov/forecasts/aeo/>

[6] An organ of the U.S. Department of Energy (DOE), EIA provides historical data about the consumption, transportation, refinement, and production of energy in the United States, North America, and the rest of the world as well the AEO forecast to 2040, please see their homepage, <http://www.eia.gov/>

[7] NEMS is a complex, multilayered system that describes energy supply and demand at the regional-level in the United States, for an introduction to it, please see, <http://www.eia.gov/oiaf/aeo/overview/>

[8] Price elasticity quantifies the strength of the consumption response to a price change—for instance, if a 50% increase in a good's price leads to a 25% decrease in its consumption, then the elasticity for this item is "inelastic" and listed as -0.5 (or 50%/-25% equals -0.5)

[9] Up to and including county or county-equivalent geographies

[10] The equivalent to gross domestic product (GDP) at the state-level

[11] Studies completed by (and special thank you to) Dr. Thomas Potiowsky, Dr. Jenny Liu, and Jeff Renfro at NERC for their original work in assessing the impact of an Oregon carbon tax, please see, <http://www.pdx.edu/nerc/nerc-faculty-and-staff>

[12] For the Portland State University homepage, please see, <http://www.pdx.edu/>

does not promote a specific policy in the manner of a think-tank, for example. In the past year, REMI studies on carbon taxes at the state-level include Massachusetts,[13] Washington,[14] and California.[15] REMI also completed a national-level carbon tax study for Citizens' Climate Lobby (CCL) with geography of the nine U.S. Census regions.[16] All of these studies, as well as this one for Vermont here, are fundamentally "tax reform" studies. None depends on a particular reason for taxing carbon dioxide. This is similar to typical analyses of existing income and sales taxes where revenue changes and economic impacts are critical while achieving larger social goals (such as changing energy consumption patterns) are a secondary concern. The same is true here. We do report results on emissions, but they are secondary, background considerations versus the tax changes and economic impacts. **We do not comment for or against the dangers posed by higher atmospheric concentrations of carbon and humankind's role in "climate change" or "global warming."** The results here do not depend on any set of beliefs regarding the former because the models do not include any "climate feedbacks," or changes to economic conditions due to changing weather patterns or sea levels related to carbon emissions. Hence, this study focuses tightly on the economics of the carbon price based around a specific set of policy designs for rates and revenues.

[13] Scott Nystrom and Ali Zaidi, "Modeling the Economic, Demographic, and Climate Impact of a Carbon Tax in Massachusetts," *Regional Economic Models, Inc. (REMI)*, July 11, 2013, <http://etr-us.org/wp-content/uploads/2014/01/REMIma.pdf>

[14] Scott Nystrom and Ali Zaidi, "The Economic, Demographic, and Climate Impact of Environmental Tax Reform in Washington and King County," *Regional Economic Models, Inc. (REMI)*, December 13, 2013, <http://etr-us.org/wp-content/uploads/2014/01/etr-wa-remi-dec-13-2013.pdf>

[15] Scott Nystrom and Ali Zaidi, "Environmental Tax Reform in California: Economic and Climate Impact of a Carbon Tax Swap," *Regional Economic Models, Inc. (REMI)*, March 3, 2014, <http://citizensclimatelobby.org/wp-content/uploads/2014/03/REMI-CA-Carbon-Tax.pdf>

[16] Scott Nystrom and Patrick Luckow, "The Economic, Climate, Fiscal, Power, and Demographic Impact of a National Fee-and-Dividend Carbon Tax," *Regional Economic Models, Inc. (REMI)* and *Synapse Energy Economics*, June 9, 2014, <http://citizensclimatelobby.org/remi-report/>

Policy Design

When imagining a carbon price at the state-level, there are "dimensions" for designing the policy around the tax and the redistribution of revenues. These dimensions include the rate of the tax in dollars per metric tons of carbon dioxide, the "tax path" (how it changes over time), and the use of revenues for some combination of tax cuts, rebates, and spending on various programs or other initiatives. The scenarios included below are but only a small set of the theoretically limitless number of possibilities for policy. REMI worked with VPIREF on the development of the exact scenarios. They attempt to balance such objectives as jobs, preserving the competitiveness of the Vermont economy, the simplicity of implementation, equity for low-income individuals and households, and maximizing the reduction of carbon dioxide emissions. To reiterate the point for clarification, REMI does not advocate these scenarios in the state of Vermont, but it has analyzed them at the behest of VPIREF. The request included three different price rates for analysis. Three rates provide a sensitivity analysis for the Vermont economy with its economy and energy sector. Different carbon prices mean different changes in energy prices and tax revenues and, thus, the rates drive the differences in the economic impact and shifts in carbon emissions. These three tax rate cases, labeled LOW, MEDIUM, and HIGH in the remainder of the report, are the focus of *Figure 1.1* below.

Carbon Price Rates

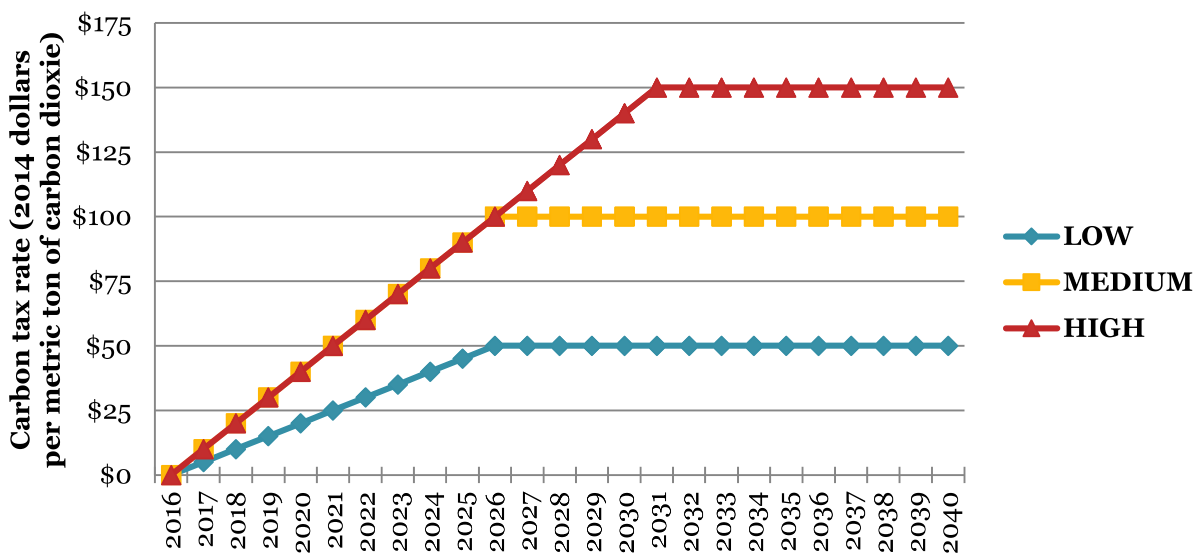

Figure 1.1 – The above lines are the three carbon price rates under analysis. All three include a linear "ramp-up" period starting in 2017 before achieving a maximum tax somewhere in the future. There are three "maximums" and two phasing patterns to achieve them. The LOW scenario sees the tax rise at $5 per year before peaking at $50 per metric tons in 2026. The MEDIUM scenario rises at $10 per year before hitting its maximum of $100 per metric ton in 2026. The HIGH scenario is similar with an annual ramp-up of $10. However, its maximum comes in 2031 at $150 per metric ton. For context, $10 per metric ton of fee translates to $0.09 per gallon of excise tax on motor gasoline. Hence, the highest of the HIGH scenario would increase the price of gasoline around $1.35 per gallon. All numbers are in 2014 dollars (including automatic indexing) and the colors remain consistent throughout the report.

The revenue recycling in this policy design is multifaceted. It includes a mixture of marginal tax cuts, rebates, credits for low-income households, and additional funds (to the tune of 10% of total carbon revenues) for state energy programs. Thus, this policy design here is not 100% revenue-neutral in the traditional sense, but it is 90% of the same. With the tax cuts and rebates, an important consideration is allocating funds amid the sectors of the economy—namely, households and groups (including businesses, nonprofits, local governments, and the state government). Some policy designs, particularly those at the level of the whole United States, favor returning all funds to households.[17] This might make more sense at the national-level. A federal carbon tax would create relatively minimal additional differences in energy prices between different regions of the country, which means it would not be likely to relocate economic activity amid sections of the United States.[18] If the federal carbon tax is $30 per metric ton in both Colorado and California, then there is little advantage to enterprises in either state against each other. Furthermore, a hypothetical federal program could include a border adjustment to deal with international trade issues. The policy design here, for Vermont, instead keeps the direct dollars "coming out" (from the tax) and those "going back" (via tax cuts and rebates) equal for the major sectors of the economy. That is, if households overall were to pay $87 in carbon fee in a given year in the state, then the summation of the funds back to them would also equal $87. The same would be true of the business sector and the nonprofit and government sector. This implies the total cost of production in Vermont does not change relative to preexisting patterns—whatever increase in energy costs sees compensation in the form of lower taxes in close to a 1:1 manner. Hence, the policy design here does not directly redistribute money between labor, capital, and the public sector broadly.

[17] Please see Nystrom and Luckow
[18] This design would also depend on businesses passing their higher cost of production to households in the form of higher prices, which makes more sense at the national-level with a border adjustment—a state would more likely see a flood of cheaper imports from other states, which might have negative impacts overall for state employment and GSP

There are several means to redistribute the funds, and details on the shares to each "channel" are below in *Figure 1.2*. With households, this could involve a higher personal exemption on earned income in the state or direct payments (such as with the Alaska Permanent Fund and its annual "oil check," which totaled $1,884 per adult in 2013).[19] Each would have a similar function in offering a guaranteed, refundable "tax break" to households. To make certain that low-income households do not feel a disproportionate harm, the lowest quintile would receive an additional share of 6% of carbon revenues. Because households would pay close to 50% of all carbon fees (and deducting 5% of that for energy programs and the 6% for low-income families), that leaves 39% for each quintile. That 39% divided into equal shares for each quintile leaves 7.8% for each 20% of households. **According to the Congressional Budget Office (CBO), a carbon tax needs to leave 12% of all revenues to the lowest 20% of households to make them "whole."[20] The extra 6% supplement would ensure them at least 13.8% (7.8% plus 6%).** This figure is direct rebates or payments only—it does not count the extra 1% to low-income households for home weatherization projects. The share paid by the for profit business sector would become cuts to corporate income taxes, and the share paid by nonprofits and the state and local government would become rebates based on their share of the sector's employment. This would help all enterprises cover higher operating expenses with tax cuts or rebates. The remaining 10% goes to efficiency and renewable programs such as converting home and business heating, transportation electrification, tax credits for solar energy, and funds for furthering home weatherization and modernization in Vermont.

Revenue Recycling

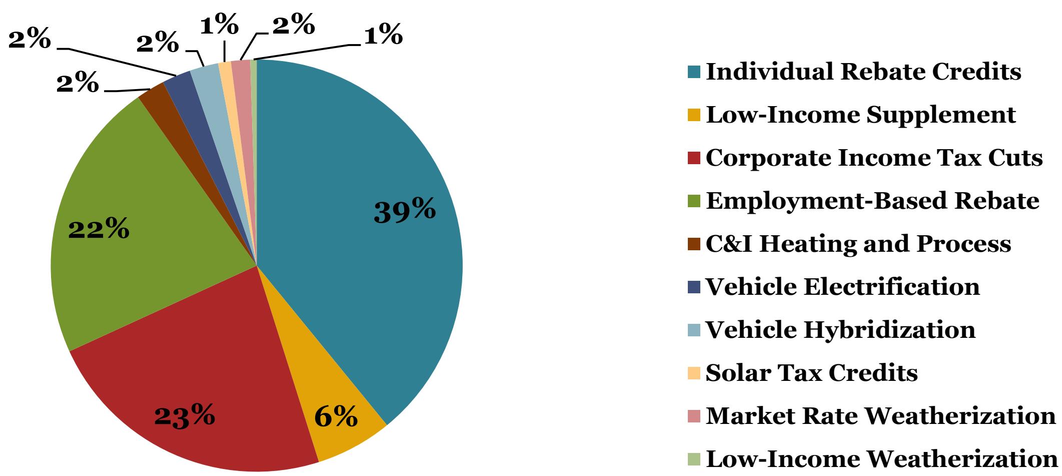

Figure 1.2 – The above shows the average shares for each type of revenue recycling. Around 45% of the money returns to households through rebates, 45% to groups with a cut to the corporate income tax and employment-based rebate, and 10% to four types of programs.

[19] Please see the homepage for the Alaska Permanent Fund, <http://pfd.alaska.gov/>
[20] Terry Dinan, "Offsetting a Carbon Tax's Cost on Low-Income Households," *Congressional Budget Office (CBO)*, November 2012, <http://www.cbo.gov/sites/default/files/cbofiles/attachments/11-13LowIncomeOptions.pdf> on pp. 8-9 and p. 13

Macroeconomic Results

Total Employment

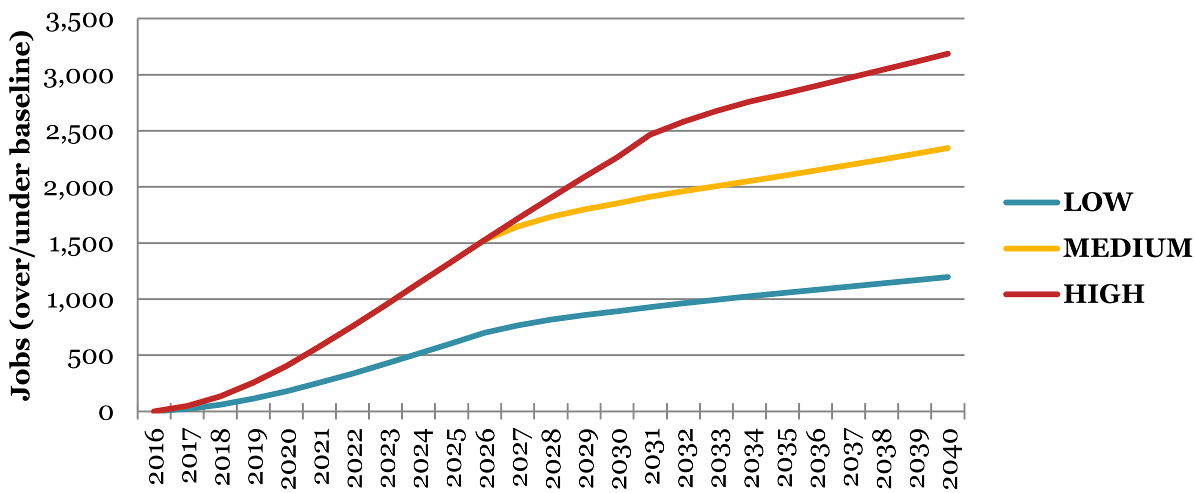

Figure 2.1 – ***The simulation results in REMI PI⁺, with inputs sourced from CTAM for Vermont and the policy design from VPIREF here, produce a net increase in employment over a baseline in the long-term in the state.*** *This increase is around 1,000 more jobs in the LOW scenario by the 2030s and as much as 3,000 jobs in the HIGH scenario by 2035. While positive come 2020, the Vermont economy currently maintains around 450,000 jobs. This means these changes are relatively small when up against the macroeconomic baseline and represent changes of 0.25% to 0.5% in the HIGH case.*

There are two primary reasons that Vermont has a net increase in employment under the carbon price revenue recycling in the model. Vermont, as well as New England overall, has very little industry associated with fossil fuel extraction and refining. Vermont has no petroleum or natural gas wells[21] and zero petroleum refineries.[22] Hence, fossil energy purchases in Vermont go towards imports to the state and lower its GSP. In 2012, for instance, Vermonters bought over $1.2 billion worth of gasoline. Around 25% of this value remains in the state with retail and distribution;[23] the loss of $900 million to imports from other states, countries, and continents is nearly 3% of GSP. Reducing these imports could "keep more dollars local," grow the Vermont economy, and create more jobs. By discouraging the consumption of an imported item, carbon pricing would encourage such schema. The second reason has to do with industry mixture. The businesses and enterprises associated with rebates, direct consumer spending, and the energy efficiency and renewable programs are more "labor-intensive" than fossil energy production and other sorts of heavy industry, which means more jobs for close to the same quantity of output. More data regarding this issue will be a focus of the industry-level analysis.

[21] According to EIA, please see, <http://www.eia.gov/dnav/ng/ng_prod_wells_s1_a.htm>
[22] While several other states in the eastern United States are on the list, Vermont has no associated data, please see the EIA data, <http://www.eia.gov/dnav/pet/pet_pnp_cap1_dcu_nus_a.htm>
[23] Cardiff Garcia, "What's keep US gas price aloft," *Financial Times*, April 2, 2012, <http://ftalphaville.ft.com//2012/04/02/945141/>

Gross State Product (GSP)

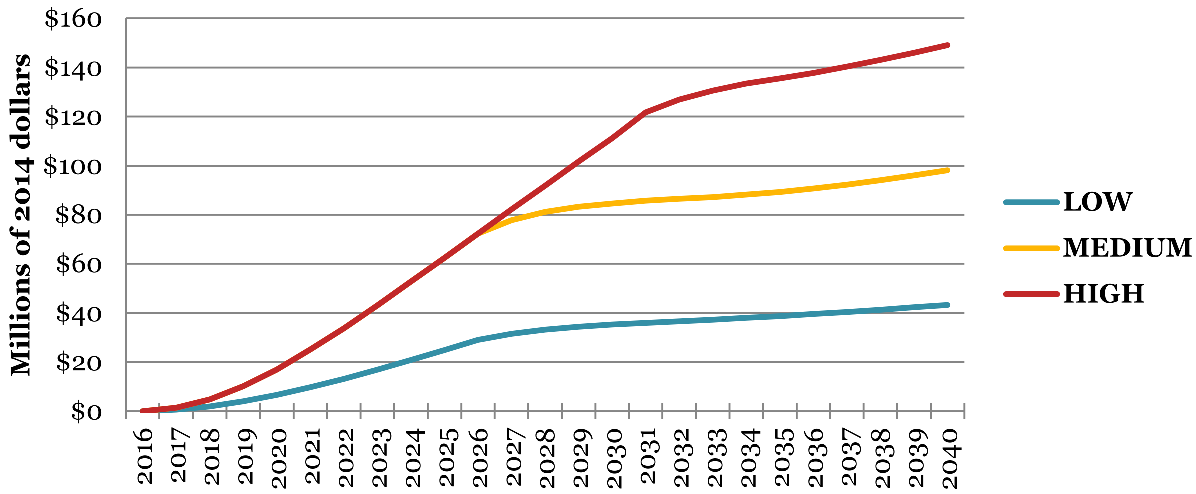

Figure 2.2 – The GSP results here are consistent with the total employment results from the previous figure. The Vermont economy is larger in the long-term because of the carbon price with rebates and tax cuts. The increased size of the state economy comes from a decrease in imports of fossil energy products, a shift into more labor-intensive and localized industries, and a proportional change in labor demand creating more income and spending in the state. For context, the Vermont economy in 2013 totaled $32 billion. This is larger than Middle Eastern states such as Bahrain or Yemen.[24] The largest increases in the HIGH scenario would be around 0.5% of this. ***The Vermont economy is likely to be larger in the future. Hence, these changes represent a difference from the current path of the economy of between 0.25% and 0.5%. This is a relatively small change in percentage terms, but it still translates into increased economy wellbeing for the state's citizens.***

[24] "Stateside substitutes," *The Economist*, January 13, 2011, <http://www.economist.com/blogs/dailychart/2011/01/comparing_us_states_countries>

GSP by Industry (HIGH)

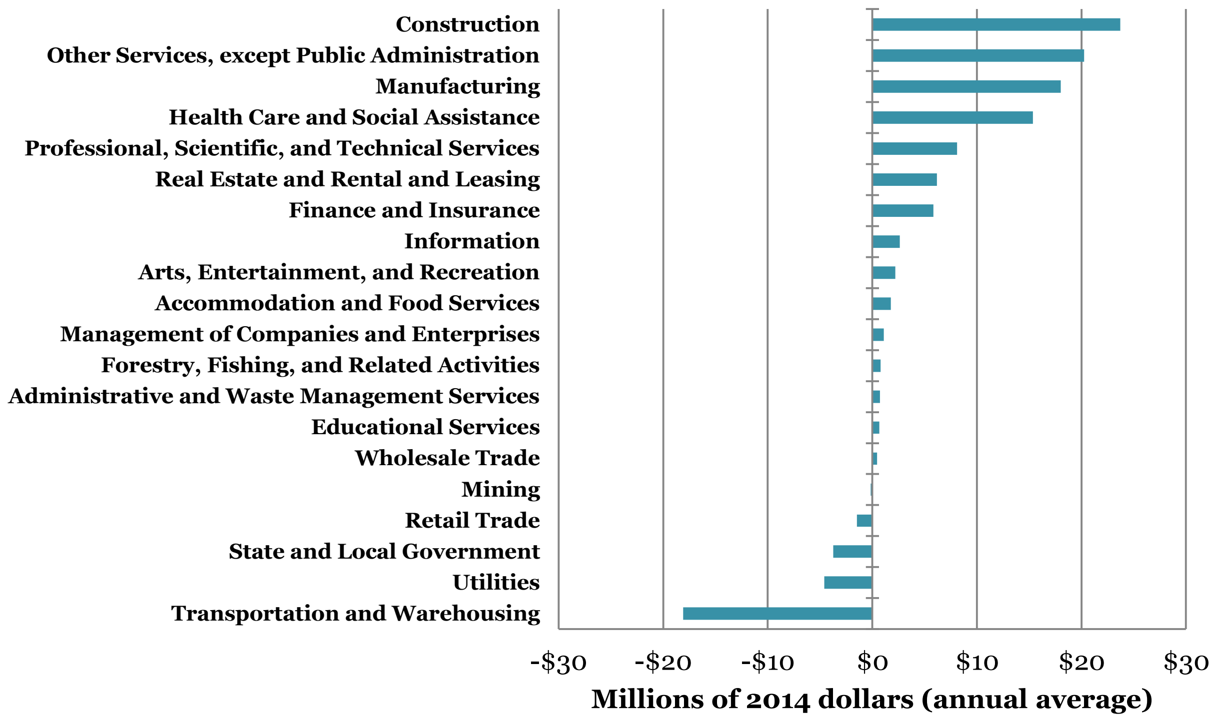

Figure 2.3 – The above shows how each industry's contribution to GSP changes because of the addition of the carbon price and rebate variables in the PI+ model. ***All of these are slight perturbations from the baseline, and no industry has an impact larger than 3% of its total addition to GSP.*** *The unit shows the "average annual impact" by counting the total change in GSP by industry from 2017 to 2040 and then dividing it by 24 to have the total impact over the total term. The industry categories are the 2-digit NAICS (North American Industrial Classification System), the standardized definition used by the U.S. Census and Bureau of Economic Analysis (BEA) for categorizing firms into different industries.*[25]

The results above derive from the structure of the industry mixture in the Vermont economy as well as the choices made about the revenue recycling by VPIREF. The industries at the very top of the list, which include "Other Services, except Public Administration" and construction, include the repair, maintenance, and retrofit activities associated with the energy programs funded with 10% of the carbon revenues. Retrofits of existing heating systems and some of the activities associated with weatherization fall under the other services (as a type of maintenance and replacement activity). NAICS considers weatherization and solar installations construction. On the other hand, the industries on the downside of the impact include those with high rates of energy usage and the retail sector. The former includes the government, which is a mammoth industry in the state and consumes significant quantities of fossil energy for heating and for operations of vehicles. Transportation and warehousing are similar. The decline in the output of the retail sector relates to its higher energy costs for operations.

[25] Please see the NAICS homepage from the U.S. Census, <http://www.census.gov/eos/www/naics/>

GSP by Manufacturing Industry (HIGH)

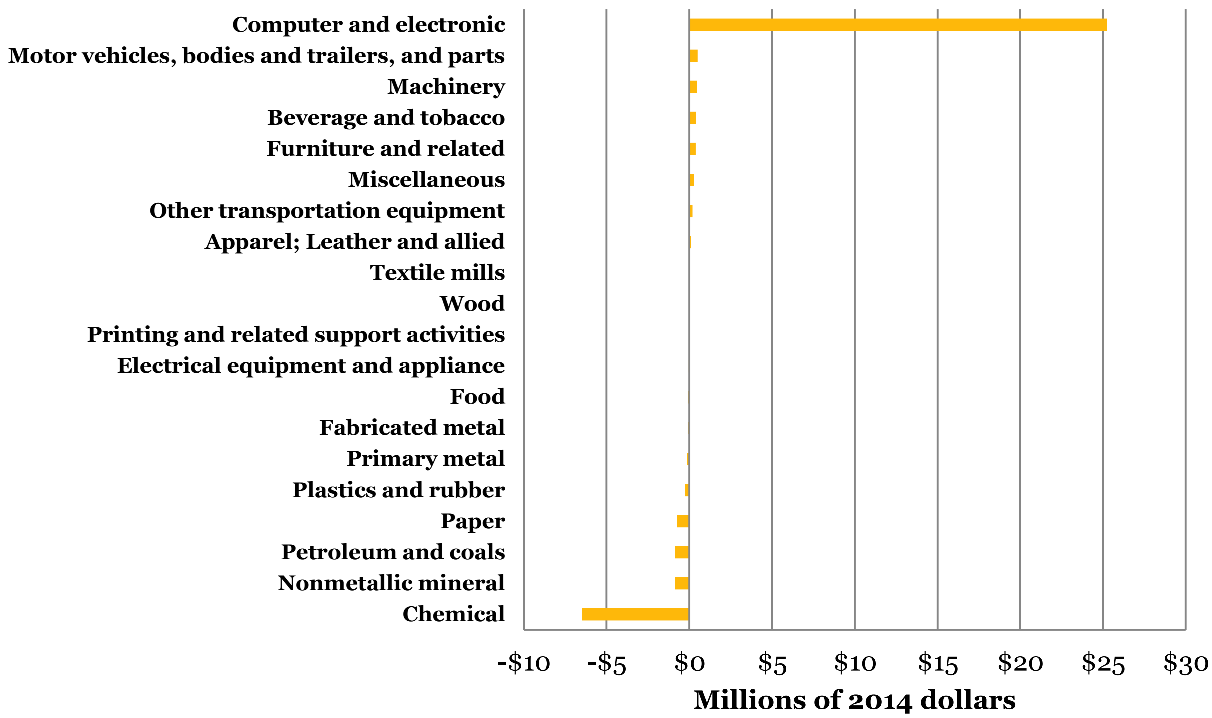

Figure 2.4 – NAICS works on a "hierarchical" setup, where the major industries from the previous figure breakdown into more detail industry classifications underneath them. Manufacturing is generally an important industry to consider in any policy analysis.

Most manufacturing types in Vermont see little change in their contributions to GSP over the time horizon with the exception of chemicals[26] and computers and electronic products.[27] The chemical industry is a major consumer of fossil energy products for energy purposes and for production, which means an increase in fossil prices might translate into a slightly smaller market share for firms of this industry in the state. Computers and electronics is a rather unique industry in the model because its market shares are so sensitive to changing costs. The firms in this industry compete on a competitive, global market, and many regions are capable and willing to host these types of firms. The positive impact to computers and electronics here comes down to two factors. First, this industry uses little liquid and gaseous fuels but copious electricity—exempted here because of its preexisting coverage by RGGI, meaning this carbon price would not change its costs to a significant degree. Secondly, while many of these firms have limited state tax liabilities, lower corporate taxes in Vermont, with the carbon price, increases returns in the state enough to bring one or two new firms (the gold bar above).

[26] "The Chemical Manufacturing subsector is based on the transformation of organic and inorganic raw materials by a chemical process and the formulation of products," <http://www.census.gov/cgi-bin/sssd/naics/naicsrch?code=325&search=2012%20NAICS%20Search>

[27] "Industries in the Computer and Electronic Product Manufacturing subsector group establishments that manufacture computers, computer peripherals, communications equipment, and similar electronic products, and establishments that manufacture components for such products," <http://www.census.gov/cgi-bin/sssd/naics/naicsrch?code=334&search=2012%20NAICS%20Search>

Employment by Industry (HIGH)

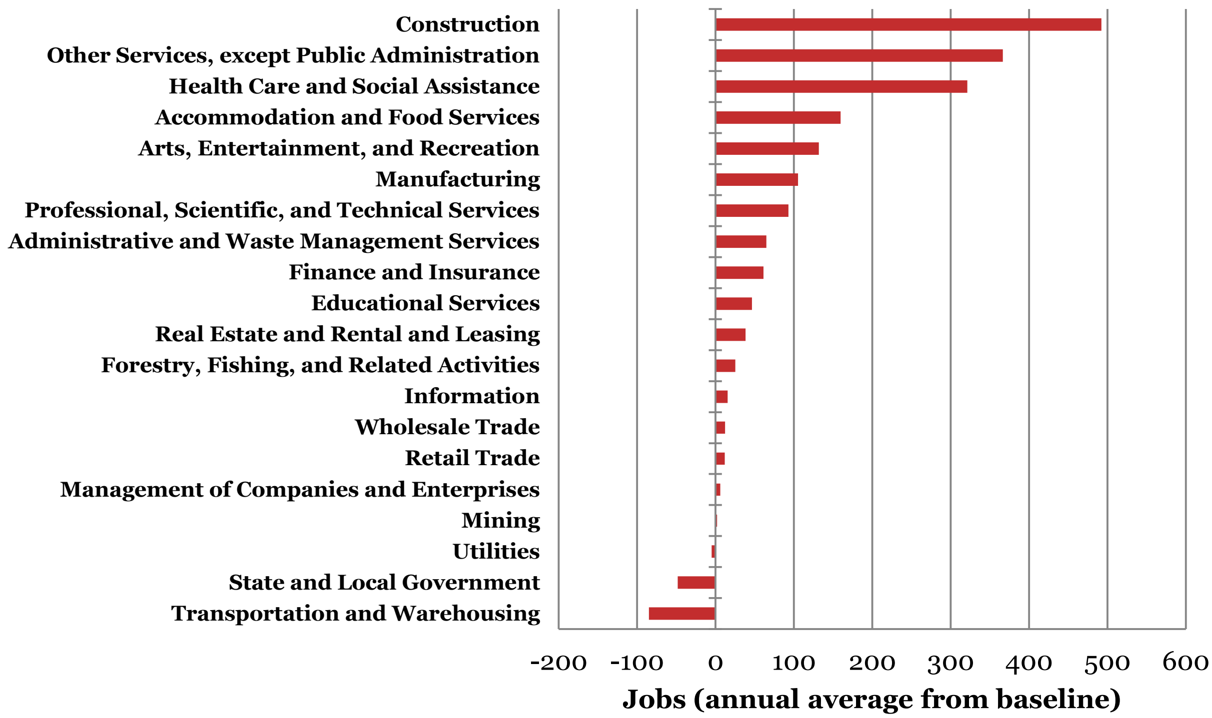

Figure 2.5 – The above shows the breakdown of employment by industry. The setup of the table is similar to the previous two with the annual average net increase in jobs for the period of 2017 to 2040 in the HIGH scenario. Most industries have a net increase in employment, particularly the service-based industries at the top, which returns to the "labor-intensity" point raised earlier in this white paper with the total employment results themselves.

One feature of carbon pricing in a state like Vermont is its propensity within the models to create extra employment in localized, labor-intensive industries. It does this while, at the same time, displacing imports of fossil fuels from other parts of the world. The choice to add 10% of the revenues to energy programs contributes to the above results, and around half of the impact to jobs for other services and construction includes the jobs related to servicing the new or expanded state programs. Other industries benefiting include those that have a business advantage from either the corporate income tax cuts or the employment-based rebate but do not use much energy in the first place. The sorts of industries include healthcare, professional services, finance, insurance, and education. Manufacturing also falls under this broad classification because of the influence of computers and electronics, as seen in *Figure 2.4* in more detail. Utilities, which include electricity generation and distribution, see very little impact because electricity is not a part of this study or policy design under the assumption that RGGI already "handles" it. Only a few industries see a decline in employment, and their declines relate to slight declines in the outputs of those parent industries. The state and local government industry "cuts back" (slightly, relative to baseline) because the employment-based rebate does not quite cover the increase to operational costs from the carbon price, though it comes close with a total change in employment of less than 100. Any long-term savings in energy costs from efficiency and renewable programs would increase these numbers, as well.

Table 2A – GSP by Detailed Industry (HIGH)

70 sector NAICS	2020	2030	2040
Forestry and logging; Fishing, hunting, and trapping	$0.1	$0.6	$0.6
Agriculture and forestry support activities	$0.1	$0.4	$0.5
Oil and gas extraction	$0.0	$0.0	$0.0
Mining (except oil and gas)	-$0.1	-$0.2	-$0.3
Support activities for mining	$0.0	$0.0	$0.0
Utilities	-$2.6	-$6.2	-$5.0
Construction	$6.7	$31.5	$36.0
Wood manufacturing	$0.0	$0.1	-$0.2
Nonmetallic mineral manufacturing	-$0.2	-$1.0	-$1.6
Primary metal manufacturing	$0.0	-$0.2	-$0.3
Fabricated metal manufacturing	$0.0	-$0.1	-$0.3
Machinery manufacturing	$0.2	$0.6	$0.6
Computer and electronic manufacturing	$6.0	$31.9	$42.1
Electrical equipment and appliance manufacturing	$0.0	$0.0	-$0.2
Motor vehicles, bodies and trailers, and parts manufacturing	$0.2	$0.6	$0.7
Other transportation equipment manufacturing	$0.1	$0.3	$0.3
Furniture and related manufacturing	$0.1	$0.5	$0.6
Miscellaneous manufacturing	$0.1	$0.4	$0.4
Food manufacturing	$0.0	$0.0	-$0.3
Beverage and tobacco manufacturing	$0.1	$0.5	$0.7
Textile mills; Textile mills	$0.0	$0.0	$0.0
Apparel manufacturing; Leather and allied manufacturing	$0.1	$0.2	-$0.2
Paper manufacturing	-$0.2	-$1.0	-$1.1
Printing and related support activities	$0.0	$0.0	-$0.1
Petroleum and coals manufacturing	-$0.5	-$1.1	-$1.1
Chemical manufacturing	-$1.4	-$8.4	-$10.6
Plastics and rubber manufacturing	-$0.1	-$0.3	-$0.5
Wholesale trade	-$0.3	$0.7	$1.2
Retail trade	-$5.0	-$1.6	$4.2
Air transportation	$0.0	$0.0	$0.0
Rail transportation	-$0.1	-$0.7	-$0.8
Water transportation	-$0.2	-$0.8	-$1.0
Truck transportation	-$2.8	-$13.7	-$19.0
Couriers and messengers	-$1.2	-$6.2	-$8.9
Transit and ground passenger transportation	$0.0	$0.3	$0.4
Pipeline transportation	-$0.1	-$0.7	-$1.0
Scenic and sightseeing transportation; Support activities for transportation	-$0.1	-$0.3	-$0.4
Warehousing and storage	-$0.1	-$0.2	-$0.3
Publishing industries, except Internet	$0.2	$1.2	$1.6
Motion picture and sound recording industries	$0.1	$0.3	$0.5
Internet publishing and broadcasting; ISPs, search portals, and data processing	$0.1	$0.4	$0.6
Broadcasting, except Internet	$0.0	$0.2	$0.2
Telecommunications	$0.2	$1.2	$1.7
Monetary authorities - central bank; Credit intermediation and related activities	$0.8	$3.6	$4.2
Securities, commodity contracts, investments	$0.6	$3.2	$4.2
Insurance carriers and related activities	$0.2	$0.7	$0.8
Real estate	$1.4	$7.1	$9.3
Rental and leasing services; Leasing of nonfinancial intangible assets	$0.1	$0.8	$1.1
Professional, scientific, and technical services	$1.5	$9.8	$15.5
Management of companies and enterprises	$0.3	$1.4	$1.7
Administrative and support services	$0.1	$0.8	$1.1
Waste management and remediation services	$0.0	$0.1	$0.1
Educational services	$0.2	$0.8	$1.1
Ambulatory health care services	$3.2	$12.6	$16.2
Hospitals	$0.4	$2.0	$3.0
Nursing and residential care facilities	$0.2	$1.1	$1.6
Social assistance	$0.7	$3.5	$5.1
Performing arts and spectator sports	$0.4	$2.3	$2.9
Museums, historical sites, zoos, and parks	$0.0	$0.0	$0.0
Amusement, gambling, and recreation	$0.1	$0.5	$0.7
Accommodation	-$0.4	-$2.4	-$2.9
Food services and drinking places	$0.9	$4.5	$6.1
Repair and maintenance	$7.3	$21.4	$22.8
Personal and laundry services	$0.5	$1.9	$2.2
Membership associations and organizations	$0.3	$1.6	$2.0
Private households	$0.3	$1.2	$1.2
State and local government	-$5.1	-$2.0	-$3.3
TOTAL OF ALL SECTORS =	$13.5	$105.9	$136.6

Table 2B – Employment by Detailed Industry (HIGH)

70 sector NAICS	2020	2030	2040
Forestry and logging; Fishing, hunting, and trapping	2	9	8
Agriculture and forestry support activities	6	25	24
Oil and gas extraction	0	0	0
Mining (except oil and gas)	0	2	5
Support activities for mining	0	0	0
Utilities	-4	-6	-3
Construction	137	625	802
Wood manufacturing	2	12	21
Nonmetallic mineral manufacturing	1	12	28
Primary metal manufacturing	0	1	2
Fabricated metal manufacturing	1	7	12
Machinery manufacturing	2	6	8
Computer and electronic manufacturing	16	52	47
Electrical equipment and appliance manufacturing	0	2	2
Motor vehicles, bodies and trailers, and parts manufacturing	2	5	6
Other transportation equipment manufacturing	1	2	3
Furniture and related manufacturing	2	7	10
Miscellaneous manufacturing	1	3	2
Food manufacturing	2	13	19
Beverage and tobacco manufacturing	0	2	4
Textile mills; Textile mills	0	2	1
Apparel manufacturing; Leather and allied manufacturing	1	2	0
Paper manufacturing	0	0	1
Printing and related support activities	0	3	5
Petroleum and coals manufacturing	0	-1	0
Chemical manufacturing	-2	-4	4
Plastics and rubber manufacturing	0	2	4
Wholesale trade	-1	15	26
Retail trade	-74	23	120
Air transportation	0	0	0
Rail transportation	0	-1	0
Water transportation	-1	-3	-3
Truck transportation	-26	-89	-86
Couriers and messengers	-9	-27	-23
Transit and ground passenger transportation	1	7	12
Pipeline transportation	0	-1	-1
Scenic and sightseeing transportation; Support activities for transportation	-1	-1	0
Warehousing and storage	-1	2	6
Publishing industries, except Internet	2	6	6
Motion picture and sound recording industries	2	7	9
Internet publishing and broadcasting; ISPs, search portals, and data processing	0	2	3
Broadcasting, except Internet	0	2	2
Telecommunications	1	3	4
Monetary authorities - central bank; Credit intermediation and related activities	4	16	17
Securities, commodity contracts, investments	14	59	65
Insurance carriers and related activities	1	5	6
Real estate	8	43	62
Rental and leasing services; Leasing of nonfinancial intangible assets	1	4	6
Professional, scientific, and technical services	19	112	175
Management of companies and enterprises	2	8	8
Administrative and support services	10	74	124
Waste management and remediation services	0	3	4
Educational services	8	55	91
Ambulatory health care services	43	166	219
Hospitals	6	38	65
Nursing and residential care facilities	6	34	54
Social assistance	31	152	228
Performing arts and spectator sports	33	146	164
Museums, historical sites, zoos, and parks	0	1	2
Amusement, gambling, and recreation	4	23	33
Accommodation	1	23	62
Food services and drinking places	34	167	237
Repair and maintenance	114	306	318
Personal and laundry services	16	56	60
Membership associations and organizations	12	50	62
Private households	17	58	55
State and local government	-46	-64	-24
TOTAL OF ALL SECTORS =	403	2,263	3,187

Table 2C - Employment by Occupation (HIGH)

95-occupation SOC	2020	2030	2040
Top executives	9	47	64
Advertising, marketing, promotions, public relations, and sales managers	1	8	11
Operations specialties managers	3	18	25
Other management occupations	9	48	66
Business operations specialists	14	70	96
Financial specialists	9	42	55
Computer occupations	8	45	64
Mathematical science occupations	0	1	2
Architects, surveyors, and cartographers	0	2	4
Engineers	5	23	30
Drafters, engineering technicians, and mapping technicians	2	10	13
Life scientists	0	3	4
Physical scientists	0	2	3
Social scientists and related workers	0	2	3
Life, physical, and social science technicians	0	3	4
Counselors and Social workers	4	20	32
Miscellaneous community and social service specialists	2	13	20
Religious workers	0	0	1
Lawyers, judges, and related workers	1	6	9
Legal support workers	1	4	6
Postsecondary teachers	-1	10	21
Preschool, primary, secondary, and special education school teachers	-4	9	27
Other teachers and instructors	0	6	12
Librarians, curators, and archivists	0	0	1
Other education, training, and library occupations	0	7	15
Art and design workers	1	9	12
Entertainers and performers, sports and related workers	7	33	38
Media and communication workers	3	12	16
Media and communication equipment workers	2	8	10
Health diagnosing and treating practitioners	11	58	87
Health technologists and technicians	6	36	56
Other healthcare practitioners and technical occupations	0	2	3
Nursing, psychiatric, and home health aides	8	43	67
Occupational therapy and physical therapist assistants and aides	1	3	5
Other healthcare support occupations	6	26	35
Supervisors of protective service workers	0	0	1
Fire fighting and prevention workers	-1	-1	0
Law enforcement workers	-3	-3	-1
Other protective service workers	3	19	29
Supervisors of food preparation and serving workers	3	15	22
Cooks and food preparation workers	7	42	63
Food and beverage serving workers	20	109	159
Other food preparation and serving related workers	4	21	30
Supervisors of building and grounds cleaning and maintenance workers	0	3	5
Building cleaning and pest control workers	12	58	79
Grounds maintenance workers	2	14	21
Supervisors of personal care and service workers	1	5	7
Animal care and service workers	2	10	11
Entertainment attendants and related workers	5	24	29
Funeral service workers	1	2	2
Personal appearance workers	5	20	22
Baggage porters, bellhops, and concierges; Tour and travel guides	0	1	3
Other personal care and service workers	23	103	141
Supervisors of sales workers	-5	7	15
Retail sales workers	-26	46	99
Sales representatives, services	7	30	37
Sales representatives, wholesale and manufacturing	2	16	22
Other sales and related workers	2	13	19
Supervisors of office and administrative support workers	3	17	25
Communications equipment operators	0	1	1
Financial clerks	11	53	72
Information and record clerks	10	58	86
Material recording, scheduling, dispatching, and distributing workers	-6	11	27
Secretaries and administrative assistants	16	75	101
Other office and administrative support workers	13	62	81
Supervisors of farming, fishing, and forestry workers	0	1	1
Agricultural workers	2	9	9
Fishing and hunting workers	0	2	2
Forest, conservation, and logging workers	1	4	3

Supervisors of construction and extraction workers	8	39	51
Construction trades workers	71	329	425
Helpers, construction trades	5	23	29
Other construction and related workers	1	8	11
Extraction workers	0	2	4
Supervisors of installation, maintenance, and repair workers	5	18	22
Electrical and electronic equipment mechanics, installers, and repairers	6	19	22
Vehicle and mobile equipment mechanics, installers, and repairers	35	105	116
Other installation, maintenance, and repair occupations	22	91	119
Supervisors of production workers	1	6	9
Assemblers and fabricators	6	24	30
Food processing workers	0	5	9
Metal workers and plastic workers	6	23	30
Printing workers	0	2	2
Textile, apparel, and furnishings workers	4	13	14
Woodworkers	1	6	9
Plant and system operators	-1	-1	0
Other production occupations	7	32	47
Supervisors of transportation and material moving workers	0	2	4
Air transportation workers	0	1	1
Motor vehicle operators	-15	-29	-5
Rail transportation workers	0	0	0
Water transportation workers	-1	-2	-1
Other transportation workers	5	18	20
Material moving workers	10	56	80
Military	0	0	0
TOTAL OF ALL OCCUPATIONS =	403	2,263	3,187

The information in *Table 2C* above, in red, examines the effects of the carbon price on the labor market in terms of occupations instead of by industry. **An occupation looks at the actual types of jobs and skills needed on the labor market instead of the industry demanding the worker.**[28] After all, most workers care more that they have a job (and one that fits their interests and skills, ideally) than they do about the NAICS of their employer. Using the occupations above illustrates the variety of workers hired by different firms. For instance, a "FIRE"[29] enterprise, such as an investment bank, will hire everything from top executives to analysts, accountants, attorneys, clerical staff, security, information technology professionals, and all the way down to crews to maintain the buildings and grounds. All of these jobs have very different skill sets, educational backgrounds, and wages. From the labor perspective instead of the industry one, a computer programmer could work for virtually any industry. A recent college graduate working on the firmware for an automobile, maritime, or aerospace equipment manufacturing company would count as "manufacturing" in *Table 2B*, even though their true background was associated with software and not physical, capital production. While specific industries in *Table 2B* may see a decline in their output or employment, workers are free to move to other enterprises or industries over time to buttress themselves against any upsets in the labor market. Looking at *Table 2C* above, very few of the occupations experience a negative impact. The few occupations with a negative impact usually lose no more than ten jobs, which is a negligible quantity over the state of Vermont and twenty years. The "worst" (in the relative sense) of the occupations is motor vehicle operations and, given this policy's focus on liquid and gaseous fuel, the decline in truck operations and drivers is a consequence of this—or, at least, for a few dozen jobs. Most occupations have a positive impact, which means Vermonters could react to these labor market changes over time.

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[28] The hierarchy for occupations is the Standard Occupational Classification (SOC), maintained by the Bureau of Labor Statistics (BLS), please see, <http://www.bls.gov/soc/>

[29] Finance, Insurance, Real Estate (FIRE)

Household Income Results

Real Disposable Personal Income (RDPI)

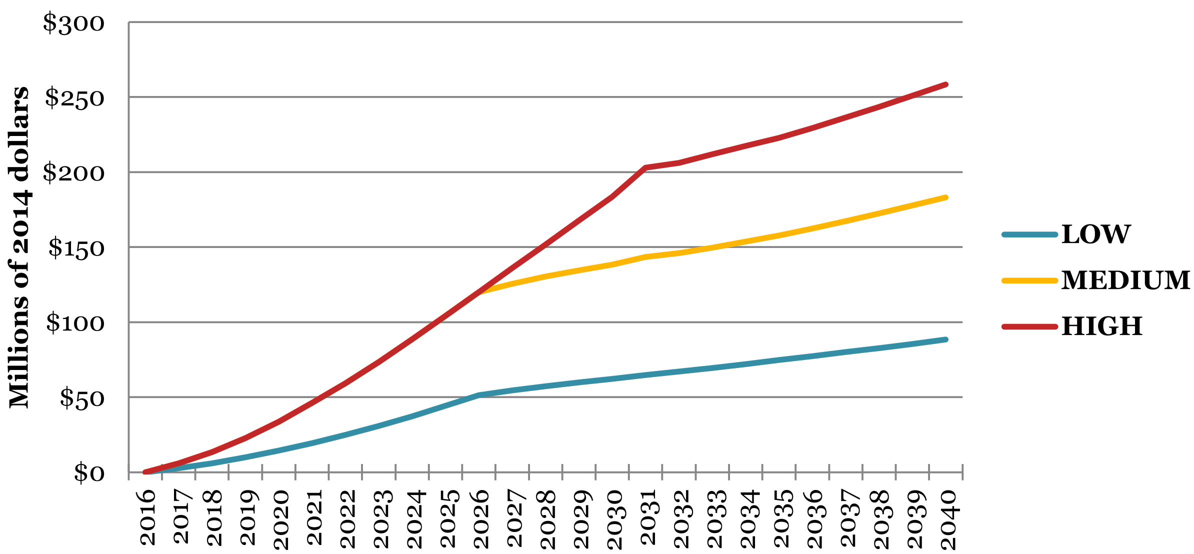

Figure 3.1 – Real disposable personal income (RDPI) is the sum of household income in the REMI PI+ model. It includes wages earned on the labor market, capital income from wealth, transfers from the government and insurance programs, and adjusts for the higher cost of living under a carbon price. While cost of living does rise because of rising expenses for fossil fuels, the impact to household income is positive in all of the scenarios in the simulation.

Cost of Living Index

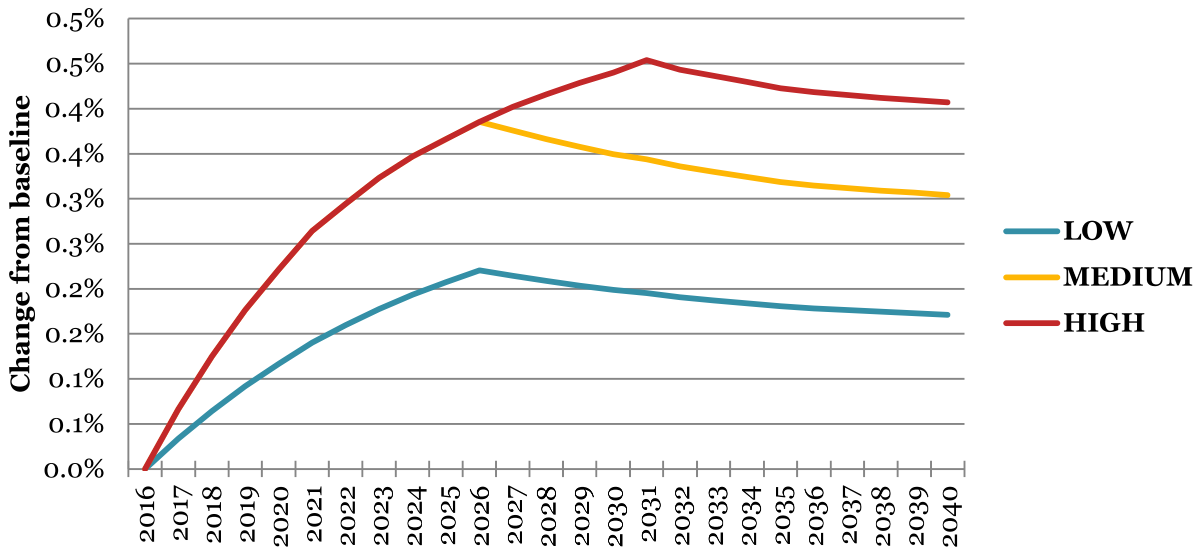

Figure 3.2 – The above is the calculation in the REMI PI+ model of the change in the personal consumption expenditure (PCE) price index. This is the model's concept for the cost of living in a region. It is similar to the consumer price index (CPI) at the federal-level. While the carbon price does make fossil commodities more expensive, energy purchases make up only a relatively small share of total consumer spending, so the impact to the cost of living against the baseline is less than 0.5% in all cases. It begins to decline in the end because the price holds steady while general prices in the economy continue to increase at a historical rate of inflation of around 2% to 2.5%. This is the equivalent to around three-months' of "normal" inflation levels. A $150 per metric ton carbon tax would raise the price of gasoline around $1.35 per gallon, which is less than a 50% change if gasoline is around $4. Versus all consumer prices for housing, healthcare, services, vehicles, furniture, electronics, education, food, and entertainment, this is a relatively small change, and hence the results above.

Compensation by Income Quintile (HIGH)

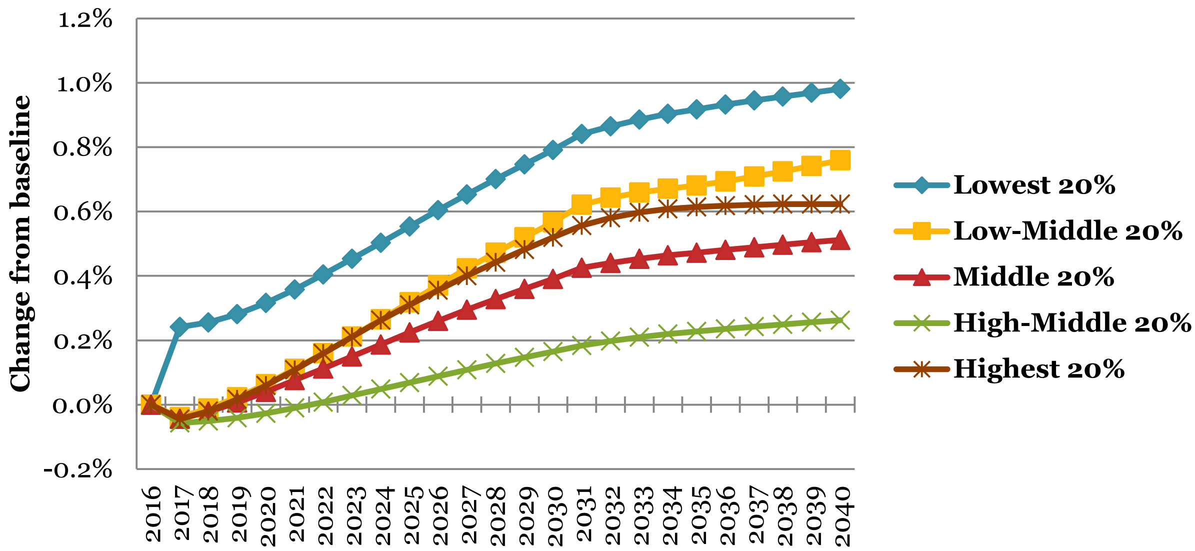

Figure 3.3 – The above illustrates the change in income by quintile for the HIGH scenario. The methodology for this involves looking at the change in employment and wages for low-wage industries (such as retail) versus high-wage industries (such as professional services) with a small adjustment for the 6% of total carbon revenues held for the lowest 20% of families. The methodology for these calculations is online.[30] The carbon fee and revenue recycling in this policy design has a propensity to create jobs and income in the lowest 40% of the income distribution (the blue and gold lines above), as well as the highest 20% of income (the brown), but even the intermediate 40% to 80% groups still have a positive impact in the long-run.

[30] *REMI* has a white paper on its website providing some more details on this methodology, please see, <www.remi.com/download/documentation/pi+/pi+_version_1.6/Income_Distribution.pdf>

Change in Energy Prices (from the Baseline)

This subsection describes the change in end-use energy prices in Vermont under the three cases for the carbon price. **These results presume either a wholesale or retail carbon price, assume 100% of the incidence ends up on end-use consumers, and exempts the electricity sector.** For a state in New England producing little in terms of fossil energy like Vermont, taxing carbon towards the "end" of the fossil fuel supply-chain would be essentially the only option in how to levy the tax. Montpelier could not levy a tax at the mine or the well in Wyoming or Texas. Taxing the border is administratively impractical (and likely illegal under the Commerce Clause of the U.S. Constitution),[31] and, hence, an excise tax at the point of local distribution or retailing is the likely outcome. The higher fuel prices below drive the models' results in terms of tax revenues generated, the economic impact, and the change in emissions. **The results below are a percentage change from the baseline and not a growth rate in any one, particular year.**

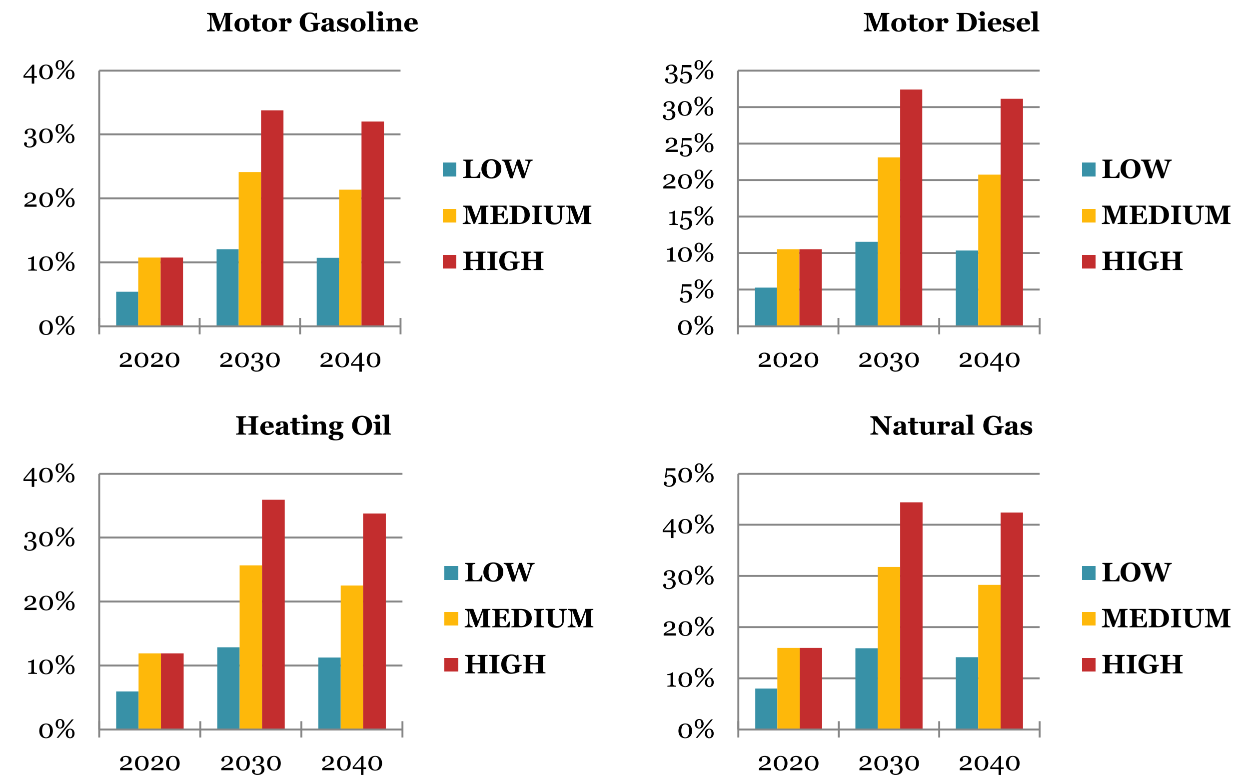

Figure 3.4 – These four categories show the effect on residential and commercial prices for fossil energy with the three carbon rates. Fossil prices would be, overall, 10% higher in 2020 in the three scenarios, though even the $150 per metric ton carbon pricing does not raise prices by more than 50% for any major commodity once it hits its maximum after 2030.

[31] Article I, Section 8, Clause 3: "[Congress shall have Power] to regulate Commerce with foreign Nations, and among the several States." The typical interpretation of this clause notes states have a right to regulate commerce within their borders, but any interstate commerce (such as the importation of fossil fuels into Vermont) is a federal issue. For discussion, please see, Darien Shanske, "State-Level Carbon Taxes and the Dormant Commerce Clause: Can Formulary Apportionment Save the World," *Chapman Law Review*, June 4, 2014, <http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2446365>

Demographic Results

Population

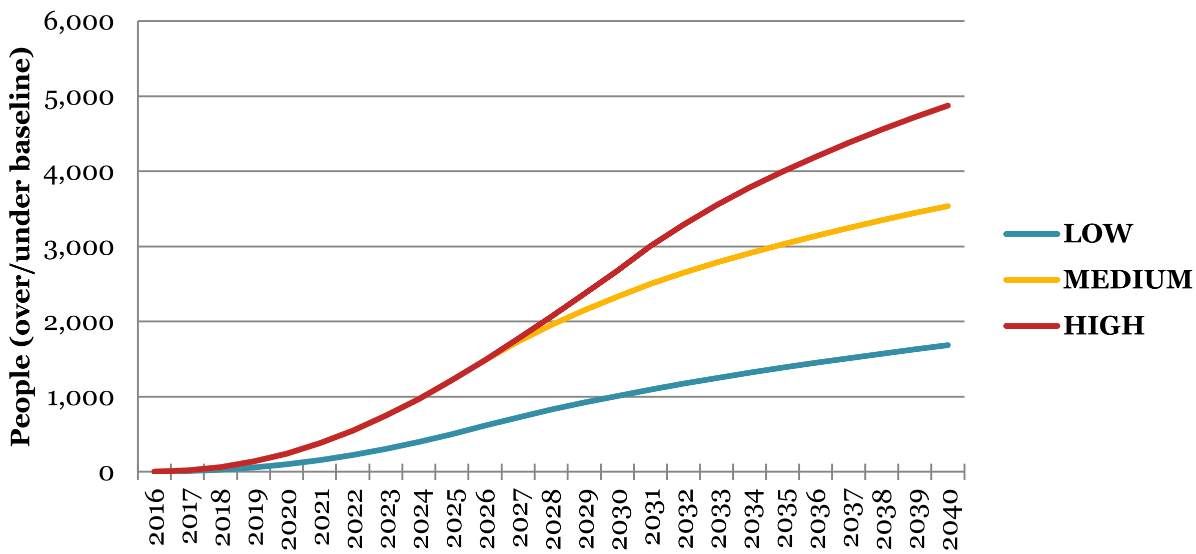

Figure 4.1 – The REMI model includes a demographic component. The demography in the model involves natural change (the sum of births minus the sum of deaths), retired migration, and the response of working-aged adults and families to conditions in the labor market. Labor is a mobile article of trade between regions in the United States. Over time, households tend to flow to the areas where jobs are easier to find, pay better, and costs are lower. The increase in employment and RDPI in the model simulations attracts more people to live and work in Vermont. The LOW case attracts around 1,500 more residents, while the MEDIUM and HIGH cases bring in around 4,000 to 5,000 additional Vermonters in the long-term.

Carbon Revenues

Annual Forecast of Carbon Revenues

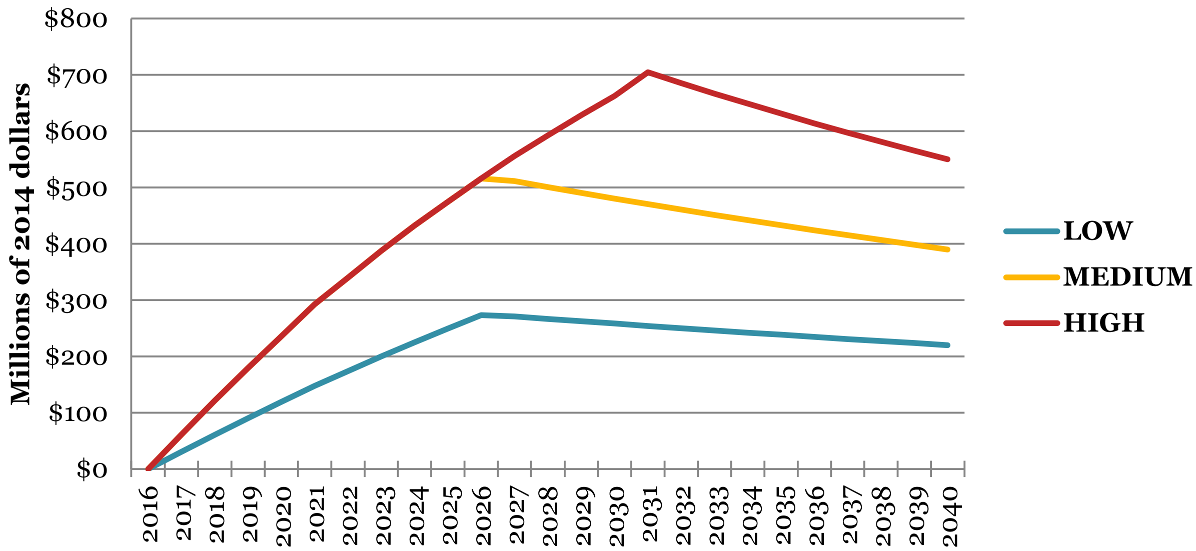

Figure 5.1 – These are the static revenue results in CTAM from the carbon pricing in Vermont. Each of the cases have an increase in revenues during their ramping and a slight decline in revenues when rates flatten thereafter. The long-term decline in revenues comes from three factors: (1) the price incentive reducing consumer demand for fossil energy; (2) state incentive programs further reducing demand; and (3) the overall growth rate of the Vermont economy increasing consumer demand. The net is a slow decline in revenues in the long-term. Progressively higher and higher tax rates generate less new revenues. One can observe this with the linear increase in final tax rates between LOW, MEDIUM, and HIGH (a $50 final increment between them) while the novel revenue from blue-to-gold is much more than from gold-to-red. For context, the Vermont state budget totals around $6 billion.[32] *The MEDIUM scenario would come close to covering 10% of the current state budget, though state expenditures are likely to increase in the future as well, which means the carbon pricing approximates up to 5% to 10% of the total sum of state expenditures.*

[32] Please see, <http://finance.vermont.gov/sites/finance/files/pdf/cafr/2013_CAFR_Final.pdf>, p. 36. This is higher than state revenues because of the federal match for transportation and Medicaid.

Size of Carbon Rebate for Each Adult (18+)

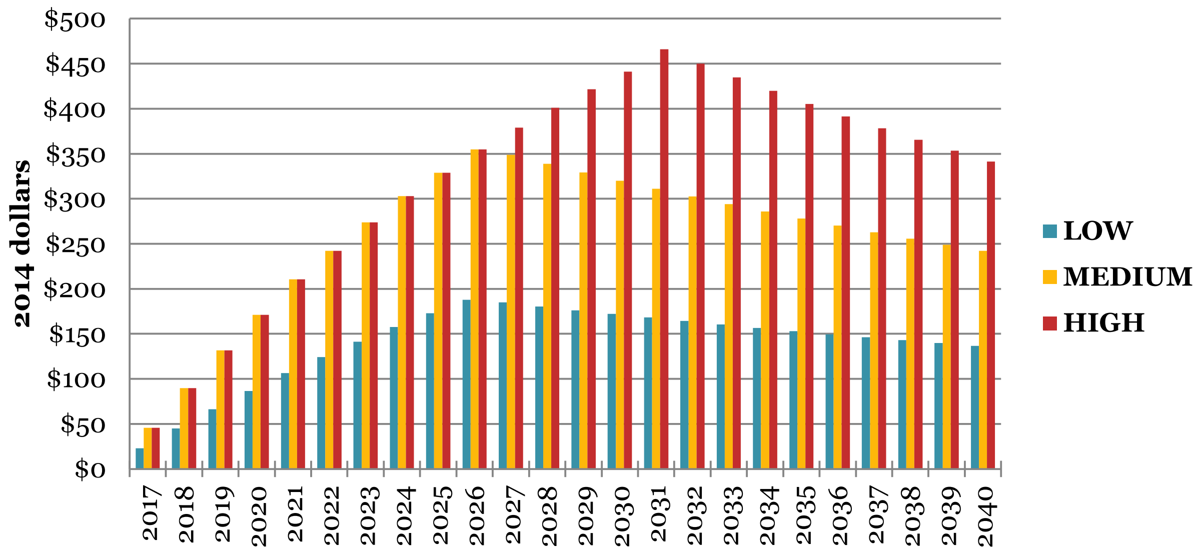

Figure 5.2 – The above bars show the rebate to the carbon price available to each adult, age eighteen or older, in Vermont. In essence, this is the money left after deducting the 10% for state energy programs and allocating the remainder between households and groups based on how much they paid in the carbon price (see Figure 5.5. below). An individual could receive as much as $450 per year in a personal exemption or an Alaska-style direct payment.

Size of Supplementary Rebate to Low-Income Adults (18+)

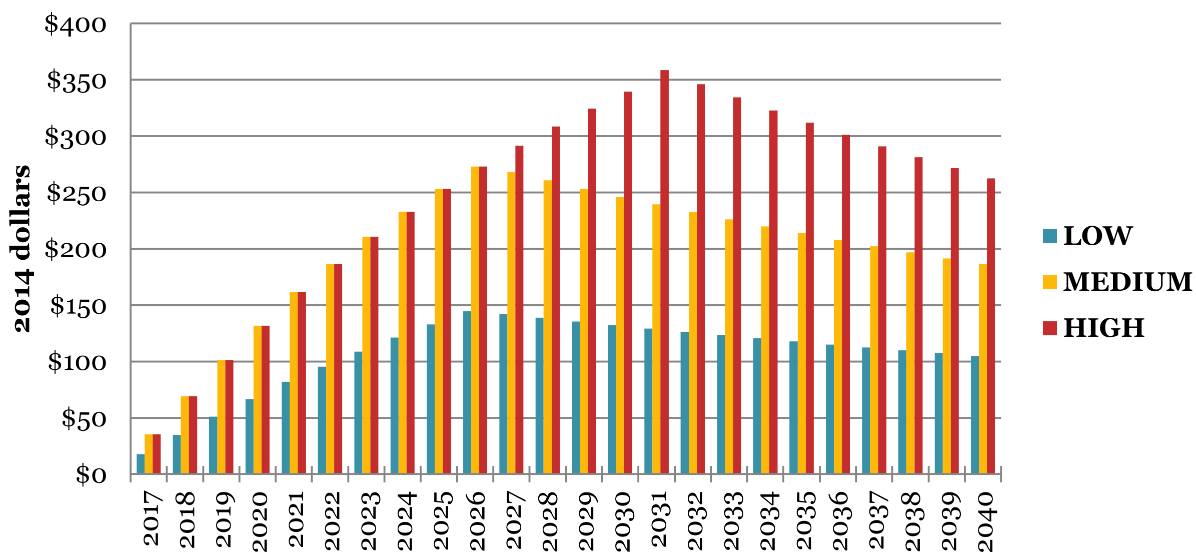

Figure 5.3 – This is the additional funds available to the lowest 20% of households to ensure they remain "whole" under this carbon tax scenario. While their cost of living will be higher (though less than 0.5% from the baseline), this additional income rebate will help to make sure they suffer no direct harms. A family with two adults could see a rebate of up to $700 here and, combined with the general rebate above, around $1,600 in total (or more) in rebate.

Carbon Revenues by Sector and Fuel Source (HIGH in 2020)

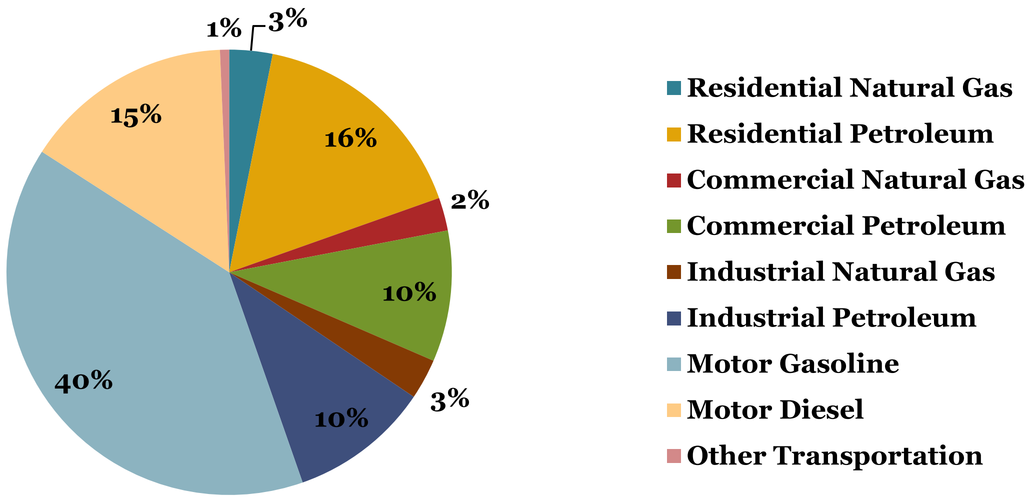

Figure 5.4 – This pie chart splits out the source of the carbon revenues by major sector of the economy and fuel source. The government is a part of the "commercial" sector above. The results are for 2020 to see the initial impact of the tax before state programs have a chance to have a large effect. The lion's share of the revenue comes from motor gasoline. Gasoline makes up the largest source of the state's current emissions and, thus, it provides the most revenue of all the categories from both household and group purchase of transportation fuels. The heating sector—the gold, green, and navy slices for petroleum—makes up the second largest sector given the relatively low available of natural gas in Vermont for heating.

Carbon Revenues from Households and Businesses/Institutions

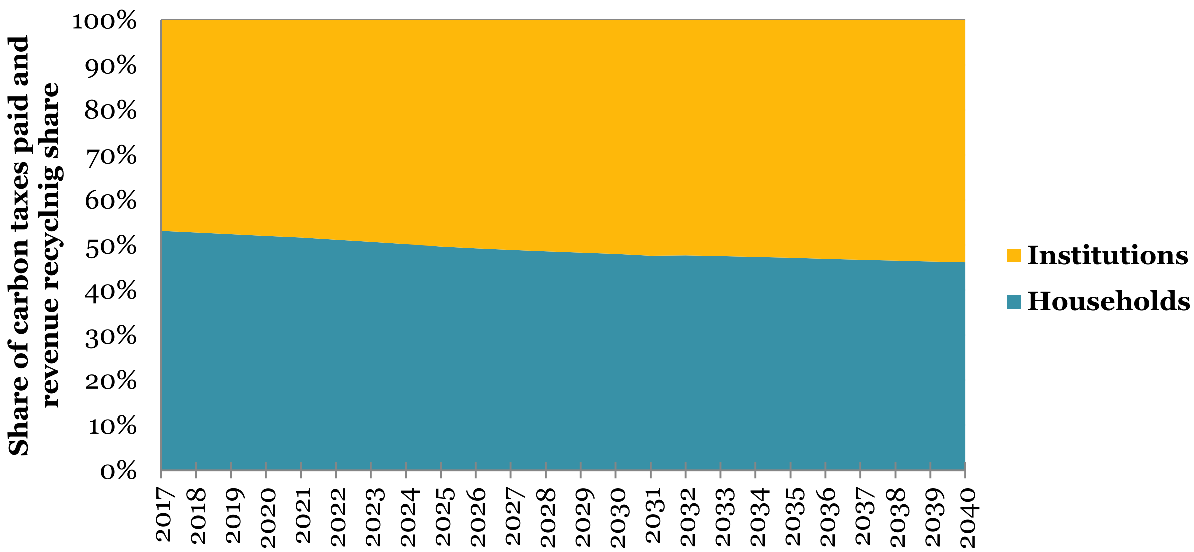

Figure 5.5 – The above block chart shows the share of carbon prices paid by each major sector of the economy and, by extension, how much they receive back of the 90% revenue-neutrality.

Carbon Dioxide Emissions

Annual Forecast of Carbon Dioxide Emissions

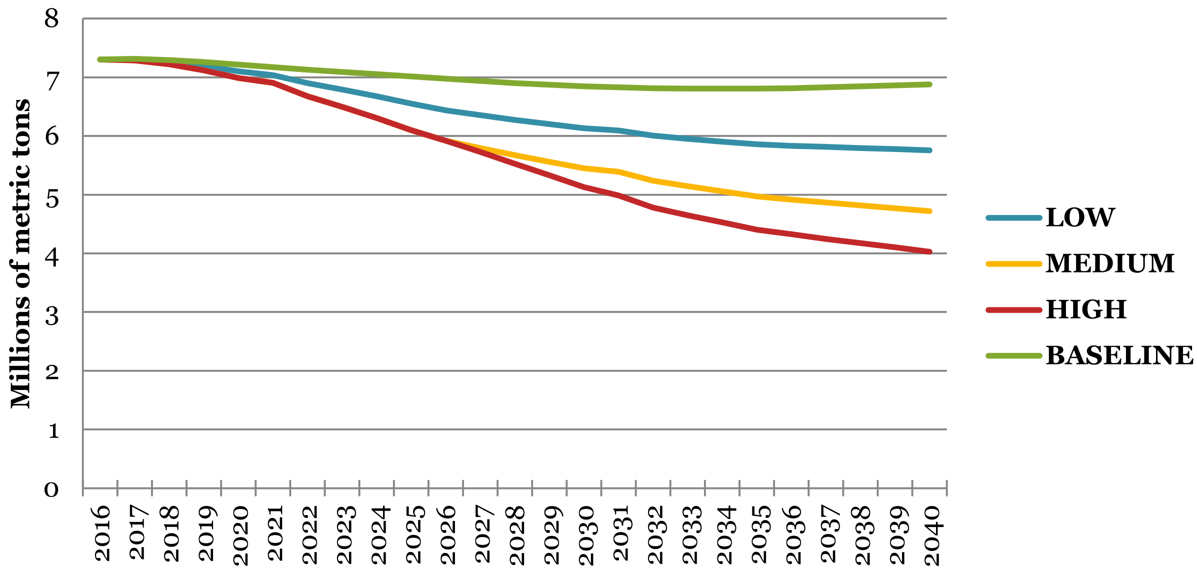

Figure 6.1 – This chart shows the emission results out of CTAM for Vermont under the three carbon scenarios. Verification data comes from the U.S. Environmental Protection Agency (EPA),[33] though EPA uses a slightly different methodology to assign emissions to regions than the data above. EPA counts emissions from liquid and gaseous fuels at their point of purchase. This does, as well. However, the EPA accounts for emissions from the power sector at the power plant's location, not at "the light bulb or Christmas tree." Because Vermont imports most of its electricity, the EPA data undercounts its contribution to carbon emissions by accounting for Vermont's electricity imports and their associated emission as carbon out of power generation in the rest of New England, Canada, New York, Pennsylvania, or down to Ohio. The results here use CTAM to "adjust back" those emissions into Vermont's count.

The pricing and revenue recycling—notably including 10% of funds to efficiency programs—would have a significant impact on Vermont's echelon of carbon dioxide emissions. According to the EIA and AEO trends regarding the New England region as a whole, the current path for emissions in Vermont with no carbon price is flat. The baseline, colored green, hovers around 7 million metric tons per year through 2040. The LOW, MEDIUM, and HIGH carbon pricing scenarios all reduce emissions significantly. Results for the LOW scenario fall to just under 6 million metric tons per year by 2040, MEDIUM to slightly under 5 million metric tons per year, and HIGH to just over 4 million metric tons. **Respectively, these results are 16%, 31%, and 41% reductions in emissions from the baseline in 2040.**

[33] Please see, <http://epa.gov/statelocalclimate/documents/pdf/CO2FFC_2012.pdf>. The emissions from Vermont in the data table track closer to 5 million or 6 million metric tons per year, but they calculate the emission from power generation in the state at zero. While this is true on the electricity production side, it is not true on the electricity consumption side where Vermonters purchase electricity imported from other states. The results above adjust for this inside of CTAM and REMI PI+.

Cumulative Saved Carbon Dioxide Emissions

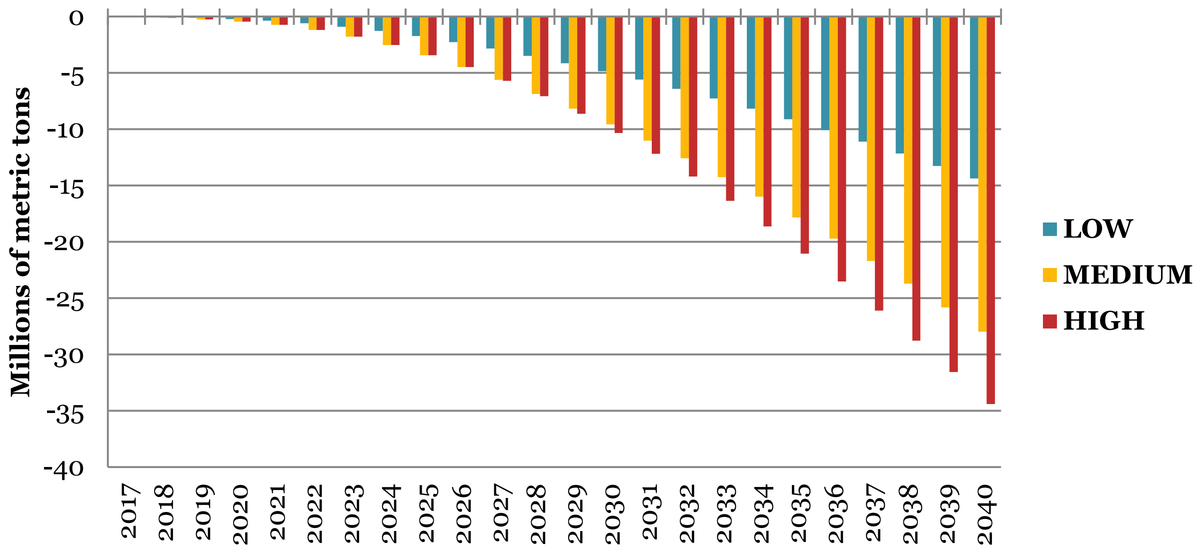

Figure 6.2 – The above restates the annual results as cumulative results over time. For instance, the 10 million metric tons saved in 2030 in the HIGH case is the sum of the annual savings under HIGH from 2017 to 2030 "horizontally" over time. ***By 2040, the eventual savings aggregates to between 15 million and 35 million metric tons of carbon dioxide. This is two to four years' worth of current emissions from Vermont. It is additionally, roughly, 3.2 to 7.4 million cars taken off roads for a year.*** [34]

[34] "Calculations and References," *U.S. Environmental Protection Agency (EPA)*, <http://www.epa.gov/cleanenergy/energy-resources/refs.html>

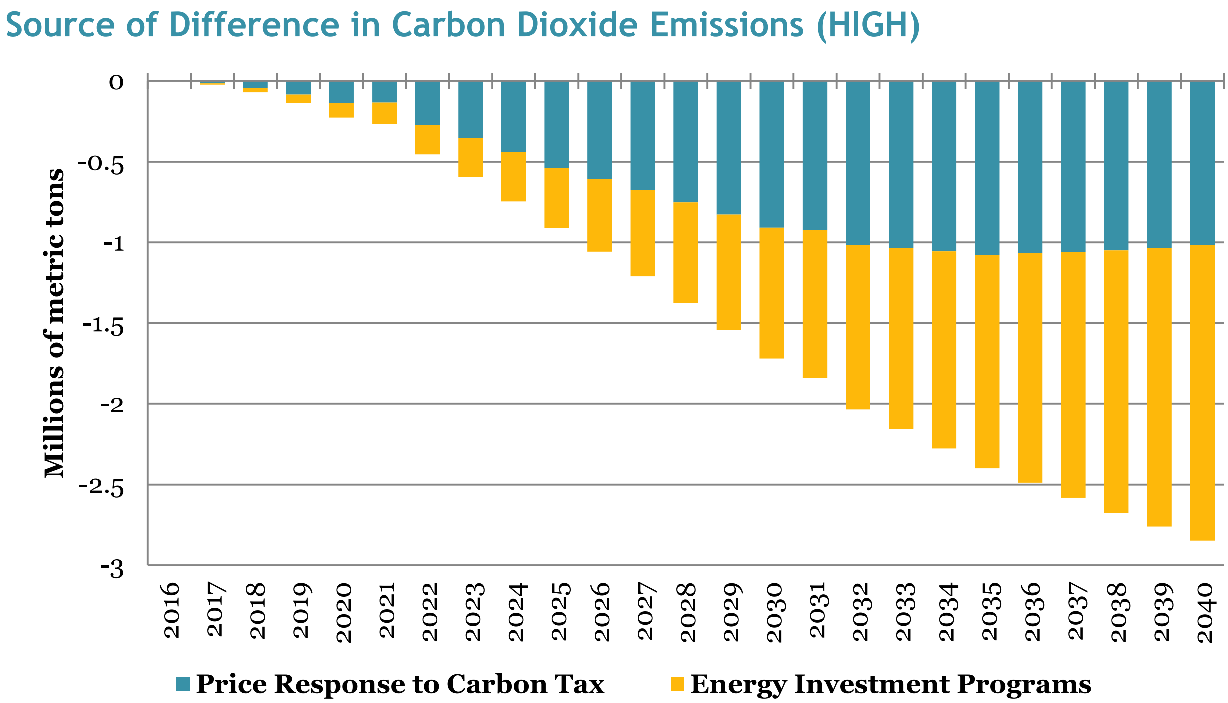

Figure 6.3 – The chart recasts the information from last page into the source of the savings. Emissions reductions from the price effect are blue and reductions from energy programs are gold. The state energy programs have more of an influence in the long-term because those benefits accrue over time (a new heating system installed in 2020 lasts into the 2030s); the HIGH scenario in particular funnels significant funding to those programs. Consumers are generally insensitive to price changes for necessity energy commodities, as well.

Regional Economic Models, Inc. (REMI)

REMI is an economics and policy analysis firm specializing in services related to modeling regional economies. Headquarters is in Amherst, MA. However, the research and the consulting related to this project originated out of its district office in Washington, DC. REMI started as a research project at the University of Massachusetts-Amherst (UMass). A professor there in the late 1970s, Dr. George Treyz, created the MEPA (Massachusetts Economic Policy Analysis) model to assess the state's plan for tolling and then expanding I-90 from Boston, then to Worcester, Springfield, and then connecting into the New York State Thruway in Albany, NY and continuing out to Rochester, Syracuse, and eventually to Buffalo. From there, Dr. Treyz generalized the methodology to all counties and states of the United States and incorporated the present firm in 1980. REMI provides software, technical support, and issue-oriented consulting across the globe for 300+ client groups in North America, Europe, Asia, and the Middle East. These groups include federal agencies, states, provinces, regional authorities, cities or counties, private consulting firms (including the major management consultants, defense contractors, as well as the "Big Four" accounting firms), non-profit research groups, foundations, and academic institutions.[35] Within Vermont, REMI clients include the Vermont Agency of Commerce and Community Development,[36] the Vermont Department of Public Service,[37] and the Vermont Legislative Joint Fiscal Office (JFO).[38] Third-party consultants have also applied the REMI PI$^+$ model to energy analysis in Vermont, such as a report in 2010 on the economic and electricity sector implications of shuttering the Vermont Yankee Power Plant nuclear facility.[39] In these clients and through these studies, REMI and PI$^+$ have always held an important part in policy discussions in the Green Mountain State.

[35] For the full list of REMI clients, please see, <http://www.remi.com/clients>
[36] Please see their homepage, <http://accd.vermont.gov/>
[37] Please see their homepage, <http://publicservice.vermont.gov/>
[38] Please see their homepage, <http://www.leg.state.vt.us/jfo/>, who also have additional information concerning the current composition of state tax revenues and state appropriations
[39] "Consensus Economic and Fiscal Impact Analyses Associated with the Future of the Vermont Yankee Power Plant," *Economic and Policy Resource, Inc.*, March 2010, <http://www.leg.state.vt.us/jfo/envy/Economic%20Analysis%20-%20Executive%20Summary10.pdf>

REMI PI+

REMI used a 1-region, 70-sector computerized model of the state of Vermont to perform this analysis. The application of PI+ was in concert with a CTAM build for Vermont ("VACTAM"), though there is a section later on the basic architecture of the CTAM model and modifications made for energy programs in simulations. PI+ is a computerized, multi-regional, dynamic, structural model. It comes as a Microsoft Windows-based program with a ribbon-based setup within its graphical user interface (GUI). The system contains over 6,000 exogenous "policy variables" used to simulate the impact of public or private decisions on the regional economy. PI+ relies on four chief methodologies from economics and regional science. The simultaneous application of these methodologies highlights their individual strengths while allowing the others to compensate for any of their individual weaknesses:

1. **Input/output (IO) tabulation** – At the core of PI+ is an IO table, sometimes called a Social Accounting Matrix (SAM). An IO model illustrates the explicit structure of the regional economy in terms of transactions from industry-to-industry. To provide a cogent example, an automobile assembly plant in Michigan will often have several parts manufacturers in Ohio associated with it, with metal fabricators in Indiana or in Pennsylvania supplying that facility. Similarly, foundries need ores provided from the Mesabi Range in northern Minnesota and shipped on trucks based in Illinois, on Great Lakes boats based in Wisconsin and railroads with headquarters in Omaha, NE and Kansas City, MO. This idea of a supply-chain "multiplier" is at the heart of an IO model. This is an important concept to include in modeling; on the other hand, there are several significant drawbacks and limitations to "pure" IO models. They include only a "demand-side" effect and include no variables on price, which are critical considerations with regards to a mechanism tied to consumption and prices like a carbon tax. An IO model has no "sense of scale"—a $1 billion input, though 1,000 times bigger, has exactly 1,000x the impact of a $1 million input. Such a setup misses the fact that larger influxes of dollars create significant "distortions" to the economy at the regional-level in terms of wages, real estate prices, and the budgetary situation of the state and local government. A single oil well in North Dakota has an impact, but thousands of them have fundamentally remade the Peace Garden State's economy in more fundamental ways than just a multiplier. Hence, PI+ relies on further methodologies to add time and scale dimensions to IO model qualities.

2. **Computable general equilibrium (CGE) model** – CGE models are a broad class of systems relying on the general principles of equilibrium economics. Adding principles from CGE modeling into PI+ adds market-level concepts to its economic structure. The typical supply-and-demand graph illustrates a "partial equilibrium"—the point where demand meets supply for a given price and quantity, the market therefore "clearing" at equilibrium. This concept from Economics 101 is important but, in reality, markets are complex and interact with one another. For example, a new factory moving into a small city would increase the availability of jobs. Given that labor is a scarce commodity (unlike in IO models), this would bid the price of labor (wages) up in the area. Having more jobs and higher wages in the example city would draw more people into the area looking for employment opportunity, high real wages, and a higher quality of life. The

new population would affect the real estate market in the area, induce more housing construction, and drive demand for services from the local government (if a young family moved into the area, then the children will attend school, which falls on local taxpayers to finance. These different markets adjust in their own way at their own rate, and PI^+ includes CGE modeling principles to account for them. CGE models usually include some concept for energy prices, as well, which PI^+ does too with explicit energy cost variables for households, businesses, and the government and in different categories for electricity, natural gas, gasoline, and other petroleum products.

3. **New Economic Geography** – Economic geography is the theory and study of the idea that there is an economy of scale for the whole economy and not just with individualistic firms, industries, and households. PI^+ uses this approach to illustrate how specialization of labor pools and supply-chains for specific tasks and industries in certain cities and in certain regions increases the productivity of the economy. For instance, the selection and availability of trained cardiologists in metropolitan areas recognized for their healthcare clusters (such areas as Rochester, MN or Nashville, TN) is higher than other cities that lack such clusters. Hospitals operating in these areas will have more of a chance to find the ideal employer/employee match than similar facilities in, for instance, Boise, ID or Helena, MT due to sheer economies of scale alone. The same would be true with other industries, such as software and technology in the Bay Area and Seattle, WA. The same concept holds for capital and physical inputs instead of labor ones. Example clusters in manufacturing would include the textiles and furniture industries in North Carolina, the commercial aircraft production lines in Washington and South Carolina, agribusiness within Iowa and Nebraska, and shipbuilding for the U.S. Navy in Virginia, Connecticut, and Maine. The strength of these clusters is a key factor in the growth and trajectory of any economy, and the REMI model includes them by adding internal adjustments to productivity based on economies of scale. PI^+ constantly assesses the "health" of these clusters in response to stimuli and including the carbon pricing.

4. **Econometrics** – REMI uses historical data to determine the parameters and inputs necessary to make the mathematics of PI^+ function. This involves the estimation of elasticity parameters (the slope of the response curves for supply and demand), the structure of the IO table, and the "time lag" on how long it takes a market to clear back to a novel equilibrium after upset. Time factors are particularly important towards making REMI into a fully dynamic model. Some markets, such as those for employment and labor, adjust rapidly while others, such as those for economic migration and for the housing market, take more time. Companies are quicker to demand labor and look to fill it than households are to up and move themselves to another county or state in pursuit of better opportunities somewhere else in the country.

The underlying methodology and equations to PI^+ are public and peer-reviewed.[40] The initial set of publications by Dr. Treyz and his research staff often appeared in such journals as *Journal of Regional Science*, *Review of Economics and Statistics*, and *American Economic Review* (AER).

[40] For the equations of the v. 1.6 of the model, please see, <http://preview.tinyurl.com/kqourr2>

PI+ uses only public data available from government statistical agencies such as the Bureau of Economic Analysis (BEA), Bureau of Labor Statistics (BLS), U.S. Census, EIA, and the U.S. Department of Defense (DOD). The macroeconomic trends and assumptions in PI+ come from the Research Seminar in Quantitative Economics (RSQE),[41] which is a research establishment attached to the University of Michigan-Ann Arbor.

REMI PI+ Model Structure

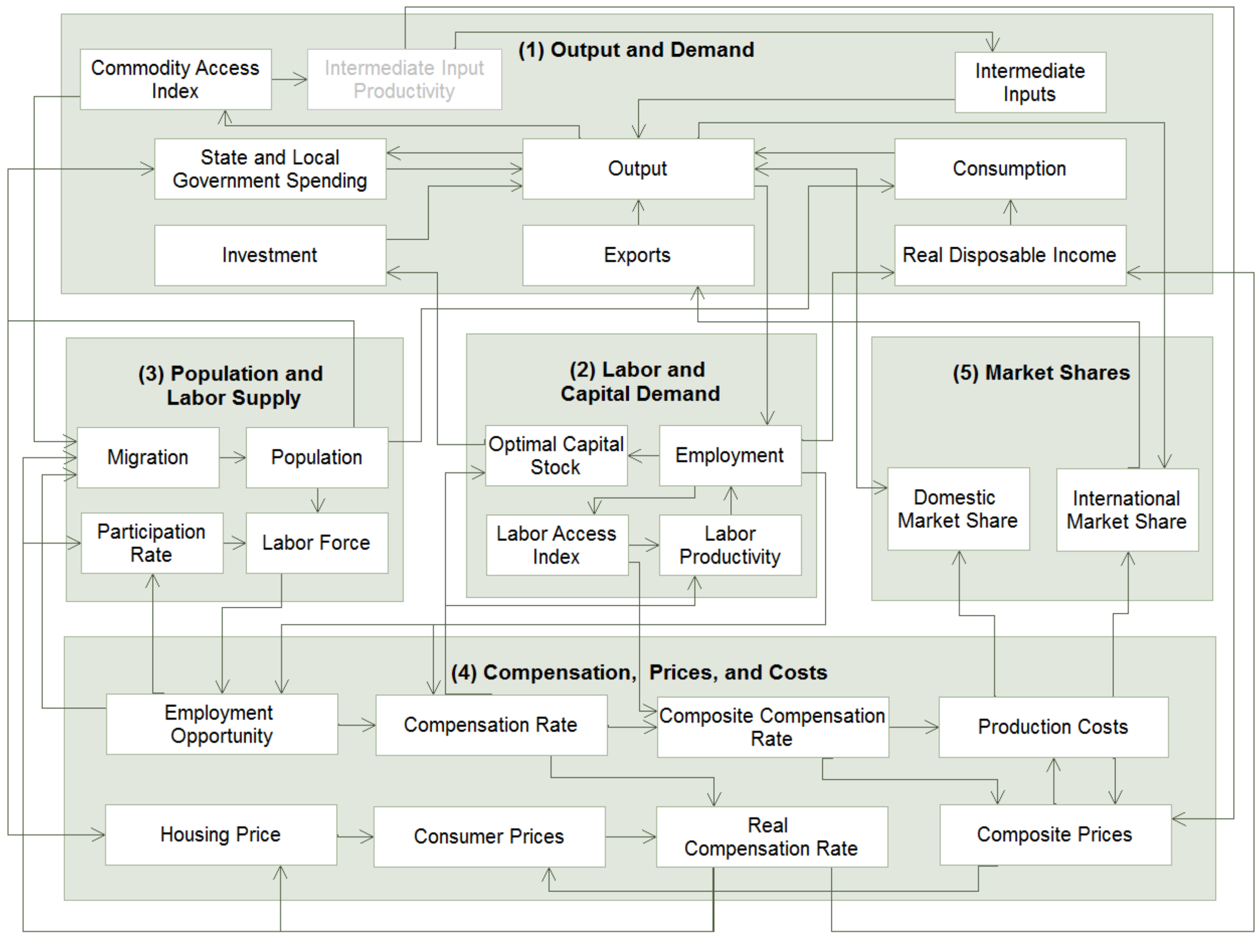

Figure 7.1 – The above is the structure of equations in the REMI model. Each rectangle is a "stock" concept while each arrow represents an equation and a flow of either dollars or individuals throughout the economy. Block 1 involves macroeconomic concepts, Block 2 looks at firm-level demand for workers and equipment, Block 3 involves households, Block 4 is the CGE portion of the model with market-level concepts for labor and housing, and Block 5 illustrates the competitiveness of the Vermont (or other) economies. Simulating a carbon tax involved changing consumer prices, production costs, but then also real disposable income and industry outputs to account for the revenue recycling sourced from VACTAM.

[41] REMI and RSQE have a long relationship dating back to the friendship of each group's founder, for their homepage and some discussion of their current macroeconomic forecasting results for the United States and Michigan, please see, <http://rsqe.econ.lsa.umich.edu/>

Carbon Tax Analysis Model (CTAM)

CTAM is an open-source, Excel-based workbook model designed to forecast state carbon dioxide emissions and potential revenues from implementing a carbon tax. CTAM uses the AEO projections spanning New England or other regions to construct a rational baseline for the current path of carbon emissions into the future. To customize CTAM to the state-level, the user must recalibrate the regional-level forecast into a state-level one by sharing the regional data down into the states based on historical data. EIA and its State Energy Data System (SEDS) have the information to do this.[42] The unit of the AEO forecast is quadrillions of BTUs,[43] and CTAM converts this into carbon dioxide based on emissions factors. Subsequently, the CTAM model applies a tax to emissions, changes consumption based on **price elasticity**, and creates a new forecast for emissions adjusted from the AEO regional (or state) baseline. Carbon tax revenues are simply adjusted emissions multiplied by the carbon tax rate. The numbers for price elasticity will be critical in this setup to determine the change in emissions and long-term revenues from a carbon tax. CTAM includes detail elasticity parameters derived from literature, and those match closely with REMI's internal econometrics for the parameterization of the consumption equation and consumer price responses in PI+.[44] However, as price elasticity is central to the functioning of VACTAM, it deserves further exploration.

"Price elasticity" is an economics concept of how strongly an agent responds to certain inputs—such as how much fossil energy consumers change their purchasing habits in response to higher prices. Working through an example is helpful. If the price of natural gas rises by 30% and the

[42] SEDS has historical data at the state-level in the format as the forecasts in the AEO at the regional-level. The most basic calculation would be that, if state Q consumed 40% of the gasoline consumed in region P in the most recent year, then state Q will continue to consume 40% of the gasoline in the AEO forecast for region P. The methodology here included some adjustments to these shares from changing economic and population growth rates between the New England states from the PI+ model.

[43] A quadrillion BTUs is a "quad," and a BTU ("British Thermal Unit") is 1,055 joules (J) or the energy needed to raise the temperature of one pound of water by 1° Fahrenheit

[44] An update to these parameters is upcoming for PI+ v. 1.7, but the previous white paper to that is here, <http://www.remi.com/download/documentation/pi+/pi+_version_1.0/Consumption_Elasticities.pdf>

purchases of the commodity fall by 15%, then the price elasticity is -0.5. Price elasticity is the ratio of the change in consumption to the change in price (-15%/30% = -0.5), which is how the CTAM model calculates how effective a price on carbon is at reducing carbon dioxide emissions. To return to gasoline, a $10 per metric ton carbon tax is approximately $0.09 per gallon in an equivalent excise tax. To go into further details from the working of CTAM, a gallon of gasoline at retail weighs around six pounds.[45] Combusting it with the oxygen in the atmosphere yields around 19.64 pounds of carbon dioxide,[46] which is 8.9 kilograms (rounded to 9 kilograms).[47] There are 1,000 kilograms in a metric ton, which means on gallon of gasoline releases around 0.009 metric tons of carbon dioxide (or $0.009 per gallon for every dollar in carbon emissions tax). If that $100 per metric ton tax makes gasoline more expensive to the tune of $0.90, this might represent a 22.5% increase in price if gasoline were otherwise $4. The parameter for the price elasticity of gasoline in this study was -0.66, which means a $100 per ton tax reduces the demand for gasoline by 14.85%.[48] One should note these example elasticity figures are the ones for the long-term—CTAM phases in the price response over time to take account of the fact it takes households and businesses time to replace vehicles, heating equipment, structures, and to change their behavior to price incentives. The motor fuels elasticity takes ten years to reach its full effect and the heating ones take twenty years to finishing phasing.

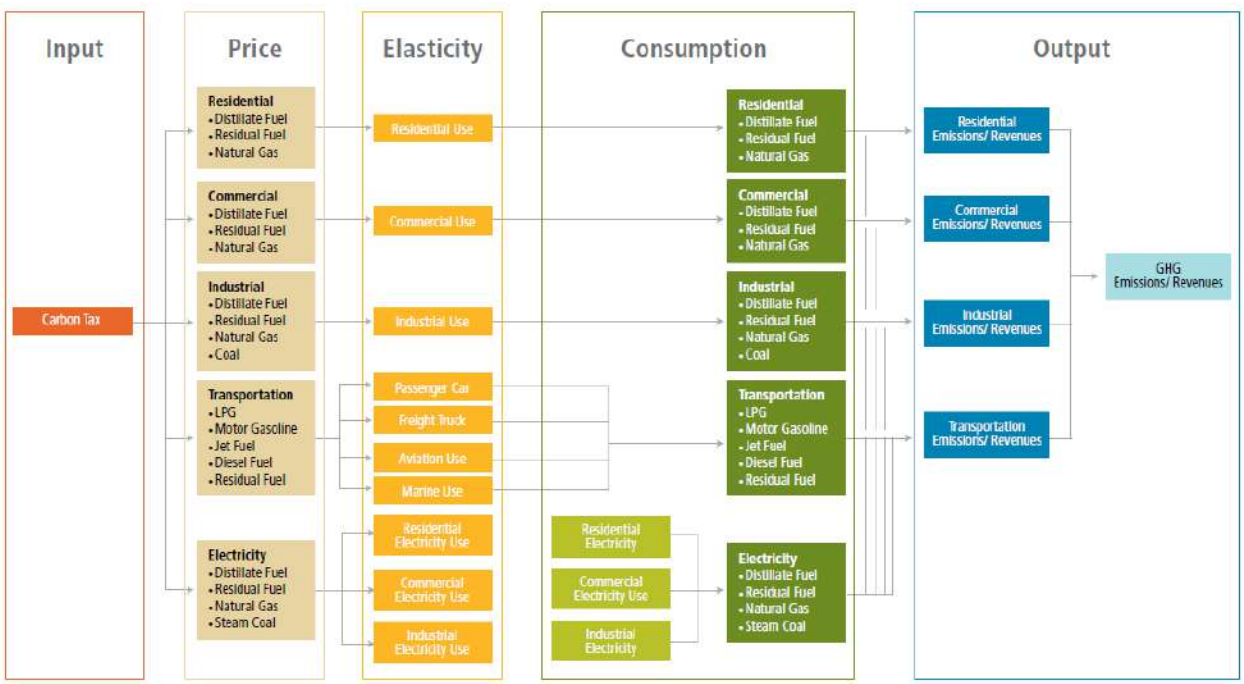

Figure 8.1 – The above flowchart covers the internal workings of CTAM by fuel type from price, to price elasticity, to the change in consumption, to tax revenues, and to the change in emissions. VACTAM did not include the electricity portion above because of RGGI.

45 Daniel Engber, "How Gasoline Becomes CO2," *Slate*, November 1, 2006, <http://tinyurl.com/7l9qfz6>
46 "How much carbon dioxide is produced by burning gasoline and diesel fuel," *U.S. Energy Information Administration (EIA)*, <http://www.eia.gov/tools/faqs/faq.cfm?id=307&t=11>
47 1 pound = 0.453592 kilograms
48 -0.66 * 22.5% = -14.85%

Energy Efficiency and Renewable Enhancements

While previous studies in CTAM and REMI PI+ only looked at revenue-neutral cases, this study was novel for allocating 10% of revenues to state programs designed to reduce emissions. These programs covered transportation, heating infrastructure, and home weatherization. The added work in CTAM to illustrate these programs first involved calculating the amount of "equipment" the 10% would procure. Second, the model enhancement approximates how much carbon dioxide the upgrades would save and then used them to make further adjustments against the AEO baseline in CTAM's results. There were four types of programs, each covering their own subsection of emissions and the economy:

- Programs related to reducing emissions from heating and industrial processes
- Credits and funding for electric and hybrid personal automobiles
- Tax credits for home and business installations of solar panels
- Funding for weatherization of housing units for individuals and families

Each had a set of parameters to make them work. These set up the composition of "stock" concepts in VACTAM—for instance, solar panels purchased with some tax credits in 2020 will continue to work for years or even decades. Hence, the major benefits to any efficiency accrue over time (as in the results in this report). The model also assumed that "help" in the form of government funding or tax credits leverages private capital towards efficiency above and beyond a price response—for heating, vehicles, and solar power, the rate of leverage produced $2.52 in private capital for every $1 in public money.[49] This is a relatively conservative and appropriate given empirical research on the performance of such programs in past applications. The model included an adjustment in consumer spending or the availability of private capital for economic activity for when money alternatively went to state energy programs.

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[49] Please see Table 3.19 of document p. 59, "Savings Claim Summary: 2013," *Efficiency Vermont*, April 1, 2014, <http://tinyurl.com/lz94luj>

Investment	Parameters
Transportation Sector[50]	• 2.25% of all carbon pricing revenues goes towards electric vehicles, 2.25% of all carbon pricing towards hybrid vehicles • Every $1 in public dollars leverages $2.52 in private money • Midsized electric vehicles and hybrid vehicle purchases replace what would be midsized sedans • The replaced cars cost $25,000, run at 39 MPG, and follow the EIA projections for a path for these to change to 2040 • Electric cars cost $57,000 in 2017, last 11 years,[51] run at 99 MPG in carbon-equivalency,[52] and follow EIA projections • Hybrid vehicles cost $31,000, last 11 years, run at 56 MPG, and follow EIA projections
Home Heat Pumps[53]	• 1.125% of all carbon revenues to installations of residential cold climate heat pumps • Every $1 in public dollars leverages $2.52 in private money • Each install costs $6,000 and lasts for 15 years • Each install saves 2.8 tons of net carbon dioxide each year in its lifespan
Business Heating and Process Efficiency	• 2.25% of all carbon revenues to business and process efficiency for the heating of structures and the operations of equipment • Every $1 in public dollars leverages $2.52 in private money • For general efficiency, $1,800 buys enough equipment upgrades and infrastructure to save 1 ton of carbon dioxide[54] for a lifespan of 17 years[55]
Solar Energy Investments	• Receives 1% of total carbon pricing revenues • Every $1 in public dollars leverages $2.52 in private money • $3,800 buys a kilowatt capacity[56] with a 2% annual decrease in costs to 2040 • The capacity factor for solar in Vermont is 13%[57] • Given the nature of the electricity grid, the type of plant most likely to produce less energy because of solar power usage is a natural gas-combined cycle plant somewhere in New England • Gas-CC plants generate 795 pounds of carbon dioxide for every megawatt-hour (MWHR) of generation instead of from solar power[58] • Each unit lasts twenty years
Market Rate Weatherization	• Receives 1.125% of total carbon tax revenues • Each market rate weatherization costs $9,000[59] • Each weatherization has a lifetime of 18 years[60] • Each unit saves 2 metric tons of carbon dioxide emissions each year[61]
Low-Income Weatherization[62]	• Receives the "first" $3 million of the 10% each year • Each low-income weatherization "unit" costs $7,200 • Each weatherization has a lifetime of 18 years • Each unit saves 2 metric tons of carbon dioxide emissions each year

Table 8A – This shows the various data inputs to the various types of state programs. ***The $3 million to low-income weatherization is "before" the percentages.***

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50 Please see the EIA data, <http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014&subject=15-AEO2014&table=113-AEO2014&region=0-0&cases=ref2014-d102413a> on vehicle efficiency; <http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014&subject=15-AEO2014&table=114-AEO2014&region=0-0&cases=ref2014-d102413a> on vehicle prices

51 "Polk Finds Average Age of Light Vehicles Continues to Rise," *IHS Global Insight*, August 6, 2013, <http://tinyurl.com/onwek29>

52 Please see Table 10 for Vermont, <http://www.eia.gov/electricity/state/vermont/>

53 Chris Neme, "Comparative Analysis of Fuel-Switching from Oil or Propane to Gas or Advanced Electric Heat Pumps in Vermont Homes," *Energy Futures Group*, June 12, 2014, <http://psb.vermont.gov/sites/psb/files/VPIREF%20Neme%20PFT%20Attachment%20B%20--%20Report%20June%2012%202014.pdf>

54 "Savings Claims Summary," Tables 3.22 and 3.24, p. 64 (full citation on previous page)

55 "Savings Claims Summary," p. 62

56 Please see, <http://www.rerc-vt.org/incentives-program/progress-reports>

57 Please see p. 22 of, "Evaluation of Net Metering in Vermont Conducted Pursuant to Act 125 of 2012," *Public Service Department (PSD)*, January 15, 2013, <http://www.leg.state.vt.us/reports/2013ExternalReports/285580.pdf>

58 Nystrom and Luckow, p. 50

59 "A Report to the Vermont General Assembly: Meeting the Thermal Efficiency Goals for Vermont Buildings," *Thermal Efficiency Task Force*, January 2013, <http://publicservice.vermont.gov/sites/psd/files/Topics/Energy_Efficiency/TETF/TETF%20Report%20to%20the%20Legislature_FINAL_1_15_13_2.pdf>

60 "Savings Claim Summary," p. 64

61 Research done by VEIC on Vermont's Home Performance with Energy Star program, email correspondence dated November 9, 2014

62 Data sources for low-income weatherization the same as market weatherization, respectively, citations for n. 59, n. 60, and n. 61 above

Integrating CTAM and REMI PI⁺

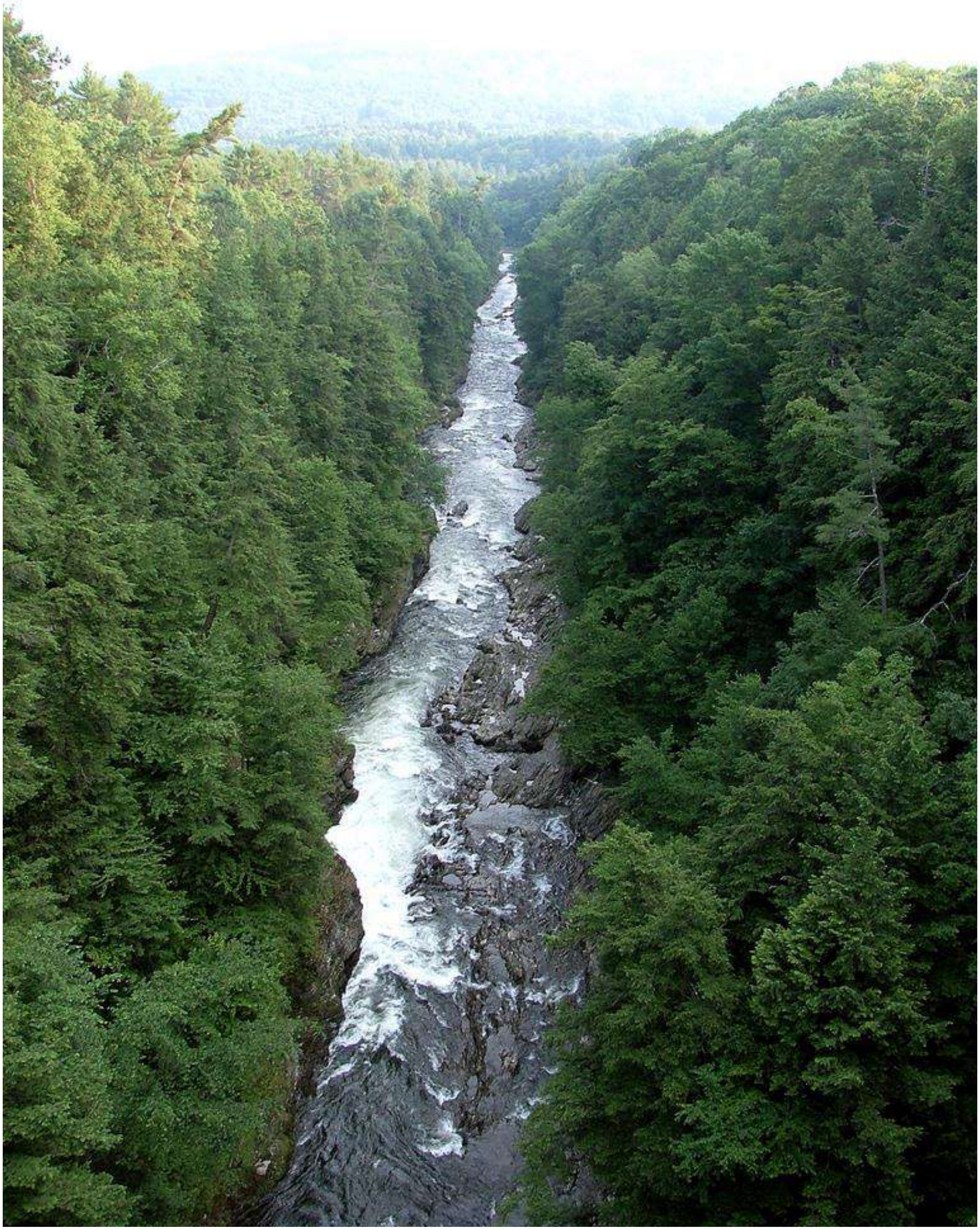
The bridge between the models required finding a way to represent the macroeconomic changes from the change in emissions, tax revenues, and revenue recycling in the VACTAM model used in this study. CTAM has four major sectors of fuel demand—residential, commercial, industrial, and transportation. These correspond to sectors and policy variables in REMI amid households and NAICS industries. AEO and CTAM have additional granularity in terms of petroleum fuel types and, hence, this "bridge" agglomerates upwards to the appropriate PI⁺ variables most of the time. The following table shows the factors out of VACTAM and the choice of variables in the REMI model used to show what it might mean for the economy:

Sector	VACTAM	REMI PI⁺
Residential	Kerosene, Distillate Fuel Oil	Consumer price (fuel oil and other fuels)
	Natural Gas	Consumer price (natural gas)
Commercial	Liquefied Petroleum Gases, Motor Gasoline, Kerosene, Distillate Fuel Oil	Residual (commercial sectors) fuel costs; state and local government spending (amount)
	Natural Gas	Natural gas (commercial sectors) fuel costs; state and local government spending (amount)
Industrial	Motor Gasoline, Distillate Fuel Oil	Residual (industrial sectors) fuel costs
	Natural Gas	Natural gas (industrial sectors) fuel costs
Transportation	Motor Gasoline	Consumer price (motor vehicle fuels, lubricants, and fuels); residual (commercial sectors) fuel costs; residual (industrial sectors) fuel costs
	Distillate Fuel Oil	Consumer price (motor vehicle fuels, lubricants, and fuels); residual (commercial sectors) fuel costs; residual (industrial sectors) fuel costs

Table 9A – The above chart maps the carbon tax revenues on the left in CTAM into the cost variables in REMI associated with higher costs of living and doing business in the state.

There were further adjustments in the macroeconomic model to adjust for the recycling of the carbon revenues. Their treatment is in the list here below:

- **Individual rebates** and **low-income supplements** were adjustments to real disposable income in the system by reducing personal taxes
- **Corporate income taxes** were the production cost variable, allocated between industries in the state based on their share of value-added
- **Employment-based rebate** went to the service sectors and the government with the production cost variable and an increase in state and local government output
- **Heating pump conversions** went to exogenous demand for the repair industry, which helps explain its strong outcome in these simulations
- **Vehicular efficiency** went towards demand for automobile manufacturing
- **Solar tax credits** included some construction demand for the installations
- **Home weatherization** went to increase the output of the construction industry



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Scott Nystrom[63] received his B.A. in history, his B.S. in economics, and his M.A. in economic history from Iowa State University[64] in Ames, IA. He has worked for REMI since 2011, and he is the main point of contact in its Washington, DC office for training, technical support, and for economic consulting. Mr. Nystrom works on a daily basis with clients across the United States and the rest of the world in state government, federal organs, provincial authorities, regional councils, consulting firms, universities, foundations, and non-profit research groups. His major projects have included economic analyses of the federal "fiscal cliff,"[65] Keystone XL pipeline,[66] the $500 billion long-range regional plan for Southern California Association of Governments (SCAG),[67] and Medicaid expansion (with county-level details) in North Carolina.[68] His work on carbon taxes includes similar analyses for Massachusetts, Washington, California, and at the national-level for Citizens' Climate Lobby (CCL) in concert with Synapse Energy Economics[69] out of Cambridge, MA. His other responsibilities include integrating energy models with REMI PI$^+$, modeling intermodal transport, assessing commuting patterns, and business development and client service travel throughout Canada and the United States.

63 Please see, <https://www.linkedin.com/pub/scott-nystrom/5b/274/337>
64 <http://www.iastate.edu/>
65 Scott Nystrom, Chris Brown, and David Brown, "Cheating the Future: The Price for Not Fixing Entitlements," *Third Way*, February 2013, <http://content.thirdway.org/publications/656/Third_Way_Report_-_Cheating_the_Future_The_Price_of_Not_Fixing_Entitlements.pdf>
66 Scott Nystrom and William W. Wade, "The Keystone XL Pipeline: REMI Estimates of Economic Impacts from Construction and Operations based on the Keystone Record," *Energy and Water Economics*, February 29, 2012, <http://tinyurl.com/nff6bnt>
67 Scott Nystrom and Zilin Cui, <http://rtpscs.scag.ca.gov/Pages/default.aspx>
68 Sara Wood, "Business Brief: Study shows expanding Medicaid would benefit NC economy," *National Public Radio (NPR)*, February 18, 2013, <http://whqr.org/post/business-brief-study-shows-expanding-medicaid-would-benefit-nc-economy>
69 <http://www.synapse-energy.com/>

Notes