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An Analysis of Decarbonization Methods in Vermont

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Key Findings

This report provides information on policies to reduce greenhouse gas (GHG) emissions in Vermont.[1] It considers both *carbon pricing policies*, such as carbon taxes or cap-and-trade programs, and *nonpricing policies*, such as electric vehicle (EV) and energy efficiency incentives, weatherization programs and investments in low-carbon agriculture. This study aims to inform the policy dialogue but is not intended to address the complete universe of policy options. The key findings are presented below.

- Emissions in Vermont have been increasing since 2011, and the state is currently well above a pathway that would meet any of its GHG emissions targets.
- Vermont is unlikely to meet its emissions targets with a carbon-pricing-only strategy unless the carbon price is substantially higher than the prices modeled in this study ($19 to $77 per metric ton of CO_2 equivalent in 2025).[2] Vermont has a high share of emissions from transportation and heating fuel use; both sectors are difficult to decarbonize through carbon pricing or nonpricing policies.
- Combining moderate carbon pricing and nonpricing policy approaches could reduce emissions to meet Vermont's US Climate Alliance target; under this approach, emissions are projected to be 32–38 percent below 2005 levels in 2025 compared with the target of 26–28 percent.[3]
  - Combining policies such as those described in the study would not meet the state's statutory 2028 target (58 percent below 2005 levels or 50 percent below 1990 levels).
- Economic modeling of a range of carbon pricing designs (without nonpricing policies) suggests:
  - The combined climate and health benefits of the carbon pricing policies would exceed the economic costs for every carbon pricing scenario considered in this report.
  - Impacts on the state's GDP, level of employment, and overall economic welfare would be very small, regardless of carbon pricing policy design.
  - A carbon pricing policy could generate $74.7–$433.8 million in annual revenue in 2025, depending on the carbon price amount and number of sectors covered.
- In choosing how to use the revenue raised through a carbon pricing policy, policymakers face trade-offs among environmental outcomes, overall economic costs, and the impacts on different types of households. Policymakers can divide total revenues across multiple uses, balancing these tradeoffs.
  - According to our modeling analysis, **per household rebates** more than offset the costs of increased energy prices for the average low-income household.
  - **Reducing taxes on wage income** would lower the overall cost to Vermont's economy relative to other options considered, but these cuts would not fully offset higher energy prices.
  - Devoting revenue to **finance nonpricing policies** would reduce emissions further, but would also impose higher costs on Vermonters, because this would reduce funds that could be used to partially or fully offset the economic impacts on households of carbon pricing.

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[1] Requested by the Vermont legislature in Act 11, Sec. C.110(3), June 2018.

[2] See http://www.rff.org/blog/2017/calculating-various-fuel-prices-under-carbon-tax to convert carbon prices into changes in various fuel prices. For example, a $20 carbon price is equivalent to a gasoline tax of $0.18 per gallon. All prices and values are reported in 2015$. To convert 2015$ to 2018$, increase the dollar value by about 6 percent. For example, $19 in $2015 is $20.20 in $2018 (BLS 2019).

[3] This report doesn't evaluate economic impacts of nonpricing policies, but some evidence indicates that reducing emissions via carbon pricing is both less costly and better for low-income households than similar reductions via nonpricing policies.

Executive Summary

This study, requested by the Vermont legislature through Act 11 in June 2018, provides objective information on methods to reduce greenhouse gas (GHG) emissions in Vermont. The report aims to inform the dialogue on climate policy in Vermont but is not intended to address the complete universe of public policy options nor offer recommendations on what policies the state should pursue. Vermont lawmakers, in consultation with stakeholders, are ultimately responsible for determining state policy to address GHG emissions, and we hope this report will aid them in their decision-making.

Vermonters are already acting to reduce GHG emissions and address climate change through the Regional Greenhouse Gas Initiative (RGGI), Efficiency Vermont, zero emissions vehicle (ZEV) standards, the state renewable energy standard (RES) and more. In 2015 (the most recent year data is available), Vermont's GHG emissions were about 10 million metric tons CO_2 equivalent ($MMTCO_2e$), a 2 percent decline from 2005 levels. However, emissions have been increasing since 2011, and the state is not on a pathway to meeting its emissions targets.[1] Vermont's emissions targets include: 26–28 percent below 2005 levels by 2025 (per the US Climate Alliance[2]) and 58 percent below 2005 levels by 2028 (per Vermont statute[3]). The state missed its 2012 target by a significant margin: actual emissions were about 12 percent below 2005 levels; the target was 37 percent below 2005 levels. If Vermont continues on its current course, it is not likely to achieve its GHG emissions goals: we project Vermont's emissions to be 11 percent below 2005 levels in 2025 in the absence of additional policies.

There are a number of policies that Vermont can pursue to further decarbonize. Each policy option has strengths and weaknesses, and each option has costs that may be unevenly distributed across Vermonters. In this report, we distinguish between two types of policies: *carbon pricing policies* and *nonpricing policies*. Carbon pricing policies such as carbon taxes or cap-and-trade programs provide an incentive to reduce emissions by increasing the price of fossil fuels in proportion to their emissions intensity; whereas nonpricing policies such as financial incentives, mandates, or direct investments do not rely on such a change in relative prices to reduce emissions. The scope of work for this project, as developed with the Vermont Joint Fiscal Office (JFO), includes a *quantitative* evaluation of the environmental and economic impacts of a set of carbon pricing policies and a limited *qualitative* discussion of nonpricing policies.

While a thorough quantitative analysis of nonpricing policies is beyond the scope of this project, we do provide a limited set of estimates to give Vermont policymakers some indication of the scale of emissions reductions possible through nonpricing policies. These estimates suggest that Vermont could reduce emissions in the range of 8–28 percent (relative to 2005) by 2025 with a comprehensive and ambitious set of nonpricing policies.[4] When this is combined with our estimates for emissions in the absence of policy, emissions are projected to be 19–40 percent below 2005 levels in 2025. However, substantial additional research and policy deliberation is necessary to determine both the specific policies to deliver these reductions and the full environmental and economic impacts of those policies.[5]

Our results indicate that, based on the pricing policies we examined, both the environmental and economic impacts of carbon pricing policies alone are likely to be relatively small, especially when compared with modeling analysis of the impacts of carbon pricing on the entire United States. Because Vermont's emissions are currently concentrated in transportation and heating, moderate carbon pricing alone is unlikely to produce the large reductions in GHG emissions that would be needed to meet Vermont's emissions targets. Historically, transportation and heating fuel uses are relatively insensitive to changes in fuel prices, and therefore we project relatively small emissions reductions in these sectors. The size of the environmental impacts of pricing policies depends on both the price and the number of sectors covered by the policy; the economic impacts depend also on how the revenues are used. Carbon revenue is an appealing feature of carbon pricing and can allow the state to address the negative consequences of carbon pricing, especially for low-income and rural households. For example, we find that using revenue for rebates (fixed payments per household) would make the average low-income households better off than they would be without carbon pricing (even ignoring the environmental benefits of the policy)—the rebates more than compensate the average low-income household for the increase in the cost of living caused by the carbon price.[6] On the other hand, our analysis shows that impacts on economic measures such as Vermont's gross domestic product (GDP) or total labor demand are likely to be negative under a rebate-only policy, but positive under other forms of revenue use—such as a reduction in the state's tax on wage income. As a result, Vermont's policymakers need to weigh the size of the overall economic costs with the distribution of those costs across households.

Below, we summarize the key results from the analysis on the environmental and economic impacts of carbon pricing in Vermont, as well as the combination of pricing and nonpricing policies.

Environmental Impacts

Greenhouse Gas Emissions

- Under the carbon pricing scenarios considered, Vermont's GHG emissions are projected to be 13–19 percent below 2005 levels in 2025 (with carbon prices ranging from \$19–\$77 per metric ton of CO2e) and 17–24 percent below 2005 levels in 2030 (with carbon prices ranging from \$24–\$98), in the absence of additional reductions from nonpricing policies.[7] For comparison, Vermont committed to emissions targets that are 26–28 percent below 2005 levels by 2025 when it joined the US Climate Alliance and the state has a statutory target of 58 percent below 2005 levels by 2028.

  - The size of reductions increases with both the carbon price and the number of sectors covered.[8] Table ES-1 reports emissions levels in 2025 under a) Transportation and Climate Initiative (TCI) cap-and-trade program focused only on the transportation sector, b) a Western Climate Initiative (WCI) cap-and-trade program that covers transportation and heating fuels, c) the ESSEX Plan, a carbon tax that covers all emissions except agricultural fuel and the electricity sector, and d) a high carbon price path ($60 in 2020 (in 2015$) rising at 5 percent above inflation annually) that covers all emissions except agricultural fuel and the electricity sector.[9]
  - Transportation and heating fuel uses are relatively insensitive (or inelastic) to moderate changes in fuel prices; emissions in these sectors are not projected to fall substantially in response to the carbon pricing levels considered here.

Table ES-1: Vermont GHG Emissions in 2025 by Alternative Policy Designs

GHG emissions relative to 2005

	Carbon Price Policy			
	TCI	**WCI**	**ESSEX**	**High Price**
Carbon Pricing-Only	-12.9%	-13.6%	-14.3%	-19.3%
Combined Pricing and Nonpricing approach	-31.6%	-32.5%	-33.7%	-38.0%

- Vermont is unlikely to meet its emissions targets with a carbon-pricing-only strategy, unless the carbon price is substantially higher than the range of prices modeled in this study.
- Carbon pricing and nonpricing strategies are not mutually exclusive. If Vermont pursued all the nonpricing policies discussed in this report, in addition to one of the carbon pricing policies considered in this report, a rough calculation suggests that the state could achieve reductions consistent with the Paris Agreement and the US Climate Alliance (26–28 percent below 2005

levels by 2025).[10] Table ES-1 also reports emissions reductions from a policy that combines the comprehensive VCAC policies and a more stringent RES policy with either the TCI or WCI cap-and-trade programs or the ESSEX Plan.

- The state's statutory goal of a 58 percent reduction in GHGs relative to 2005 by 2028 will be difficult to achieve with practical and realistic carbon pricing or nonpricing approaches, or a combination of both. However, the *high* price path modeled in this study ($60 in 2020 (in 2015$) rising at 5 percent above inflation annually) when combined with the comprehensive set of nonpricing policies, is estimated to produce emissions in 2030 that are 51 percent below 2005 levels—not far off the 2028 target.
- Emissions reductions from a Vermont-only policy (rather than a regional policy, such as TCI or RGGI) are expected to be partially offset by changes in emissions in neighboring Northeast states (a concept referred to as *emissions leakage*), though the projected leakage is very small in all scenarios studied: 0.2–2 percent of Vermont's emissions reductions are projected to be offset by increases in other states.
    - Drivers shifting their gasoline purchases to neighboring states such as New Hampshire could erode the effectiveness of a Vermont-only carbon price, but it is difficult to predict how much drivers will change their behavior.
    - A policy that covers all states in New England would not significantly change emissions reductions in Vermont (compared with an otherwise similar Vermont-only policy), but it would reduce emissions leakage, remove the incentive to shift fuel purchases to other states, and lead to much greater overall reductions in US GHG emissions.

Local Criteria Air Pollutant Emissions

- Decarbonization will lead to reductions in local criteria air pollutants that harm human health, such as nitrogen oxide (NO_x), ammonia (NH_3), carbon monoxide (CO), sulfur dioxide (SO_2), particulate matter (PM_{10} and $PM_{2.5}$), and volatile organic compounds (VOCs).[11]
    - NO_x emissions are most responsive to carbon pricing; in 2025, emissions are projected to fall 2.1–11.6 percent relative to baseline, depending on the price and sectoral scope of the policy.
    - $PM_{2.5}$ emissions are least responsive to carbon pricing; in 2025, emissions are projected to fall 0.1–0.7 percent relative to baseline.
    - Using estimates on the value of reduced mortality and morbidity from reduced $PM_{2.5}$, NO_x, and SO_2 emissions (EPA 2017), reductions in these emissions are projected to provide annual benefits of $6.7–$38.9 billion (in 2015$) to Vermonters in 2025.[12]

Economic Impacts

The economic impacts of carbon pricing depend on the level of the price, the sectors covered, and how the revenue is spent. The use of revenue is as important as (or more important than) the price and sectoral coverage in determining the economic impacts of a carbon pricing policy. Macroeconomic, employment, and distributional impacts of carbon pricing all depend significantly on how the revenue is used. Additionally, alternative revenue uses often feature trade-offs between *efficiency*, the overall cost of the policy, and *equity*, the distribution of those costs across households. Finally, with few exceptions, we find that carbon pricing is not a free lunch; the gross cost (i.e., ignoring all environmental benefits of the policy) for the average Vermont household is positive. However, we also find that the benefits—reduced damages from CO_2 emissions and reduced health damages from local air pollutants—exceed costs for every carbon pricing scenario considered in this report.

Carbon Revenues

- A carbon pricing policy would generate significant carbon revenues for the state of Vermont. In 2025, the revenues are projected to be $74.7–$433.8 million (in 2015$), depending on the price and breadth of sectors covered. To put these numbers in comparison, in FY 2015, Vermont's income and estate taxes raised $843.9 million, and the consumption and property taxes raised $1,139.2 million and $1,062.1 million, respectively (VT JFO 2017).
    - Carbon pricing policies will also reduce revenues collected from existing taxes in Vermont, such as income and gasoline taxes, and increase the spending necessary to provide government services. A truly revenue-neutral policy must offset those effects.

State Gross Domestic Product and Sectoral Impacts

- With a carbon pricing-only policy, Vermont's state GDP is expected to be –0.01 to –0.09 percent lower in 2025 than it would be if the state does not adopt any additional decarbonization policies (business as usual, or BAU) and if the revenues are returned through fixed dividends (i.e., lump-sum rebates) to each household.[13] For example, if, in the absence of carbon pricing, state GDP would grow at an annual rate of 1 percent from 2018 to 2025, then the average rate of state GDP growth under these carbon pricing policies would be 0.987–0.997 percent over the same time period—these are changes that would be difficult to distinguish from statistical noise. By comparison, Vermont's state GDP fell over 1.6 percent between 2008 and 2009 during the last national recession.
    - The impacts are largely concentrated in the natural gas distribution sector (if natural gas heating is covered by the carbon price). Small but negative impacts in the construction, trade (fuel dealers and gas stations), and transportation (including trucking) sectors are partially offset by increases in output in communication and information and service industries.

    - The agricultural sector is projected to experience small declines in output, –0.1 to –0.5 percent lower output in 2025 compared with BAU, depending on the carbon price.
- If revenues are used to reduce the state's taxes on wage income, the model projects small increases in Vermont's state GDP (0.1 percent greater in 2025 than it would have been without the policy). Using the revenue to subsidize electricity rates produces a similar (but smaller) increase.
    - Relative to the policy with lump-sum rebates, industries that experience reduced output have smaller reductions and industries that experience increased output have larger increases when revenue is used to reduce taxes on wage income.
    - The electricity transmission and distribution sector experiences significant increases in output when revenue is used to subsidize electricity rates as demand for electricity increases with the decrease in retail rates.
- While policymakers may choose to allocate some portion of carbon revenues to financing various nonpricing policies or clean energy investments, it is beyond the scope of this analysis to quantitatively evaluate the macroeconomic impacts of such revenue use because of the difficulty of evaluating how that spending will be divided across industries and what economic effects it will have. Such investments could theoretically increase or decrease state GDP, but there is little empirical evidence on the state-level macroeconomic effects of such policies.

Shifts in Labor Demand

- The impacts on labor demand (total hours worked) largely mirror the impacts on output. Carbon pricing policies that decrease output relative to BAU (i.e., policies that use revenue for lump-sum rebates) will decrease labor demand, and policies that increase output relative to BAU (i.e., revenue used for cuts in other taxes or reductions in electricity rates) will increase labor demand.[14]
- We have not modeled the labor market effects of nonpricing policies. These policies could theoretically increase local employment and wages, for example, if they were to invest in infrastructure that boosts labor productivity in Vermont—but further analysis is required to estimate these potential employment impacts.

Changes in Economic Welfare

- The change in aggregate economic welfare, the most complete measure of the economic costs to households associated with a decarbonization policy, captures the impacts of changes in both prices and income on Vermont as a whole, but excluding all environmental benefits from the policy. These changes significantly depend on how the revenue is used.

  - When revenues are returned to households via rebates, total economic welfare falls $4.3 million to $47.9 million (in 2015$) in 2020; in 2025, total economic welfare falls $7.1 million to $61.2 million (in 2015$), depending on the price level and the scope of sectoral coverage. These estimates reflect an average change in economic welfare of about $20 to $100 per Vermonter.
  - When revenues are used to finance electricity subsidies, the change in economic welfare is about 20 percent smaller than the change in the policy with rebates; the subsidies reduce the economic impact of the carbon price by reducing the price of electricity.
  - When revenues are used to finance reductions in Vermont's tax on wage income, the model projects an *increase* in aggregate economic welfare, even before considering the environmental benefits of the policy.[15]
  - Modeling the change in economic welfare from dedicating revenue to nonpricing policies is beyond the scope of this study, though most evidence suggests it will be costlier than the other revenue options considered in this study.[16]

Net Benefits

- To determine whether the policy passes a cost-benefit analysis, the change in total economic welfare of each carbon pricing policy must be compared with the value of the environmental benefits, which incorporate reduced climate change damages and public health benefits from reduced air pollution. To evaluate the monetary benefit of reduced climate damages, we multiply the reductions in CO_2 emissions by the social cost of carbon (SCC).[17] For nonclimate health benefits, we use the estimates on reduced mortality and morbidity from reductions in local air pollutants, such as $PM_{2.5}$, NO_x, and SO_2 emissions.[18]
  - The combined climate and health benefits exceed the change in economic welfare for every carbon pricing scenario considered in this report, ranging from $7.1 million to $19.7 million in 2025.
  - As shown in the report, the climate and health benefits of carbon pricing policies are of similar magnitude.
  - The SCC required to justify the carbon pricing scenarios on a cost-benefit basis rarely needs to exceed $10 under the more moderate pricing scenarios. For example, the benefits of the WCI cap-and-trade program would still exceed the change in economic welfare in 2025 as long as the benefit of reduced CO2 emissions was greater than $5 per ton reduced (in 2015$).
  - Our analysis does not compare the climate and health benefits associated with the implementation of nonpricing policies to the costs of those policies. Both climate and health benefits could be large for such policies.[19]

Changes in Economic Welfare across Households

- The aggregate costs of these policies will not be evenly distributed across households. In Vermont, low-income and rural households spend a larger share of their income on fossil fuels than the average household, and thus will be disproportionately affected by higher energy prices. But that effect can be offset by the use of carbon pricing revenue, and in many cases these households would be financially better-off than they would be without the policy, even before considering any climate or health benefits—as shown in Table ES-2 below, where the two lowest-income quintiles (Quintiles 1 and 2) are better off with carbon pricing compared to no carbon pricing under all policies shown, when revenues are returned to households as rebates.
- Table ES-2 summarizes the change in economic welfare across income quintiles and urban/rural households for the TCI and WCI cap-and-trade programs, and the ESSEX Plan and high price carbon tax scenarios. The TCI and WCI cap-and-trade programs and the high price carbon tax scenarios rebates 100 percent of the revenue to in per-household rebates; the ESSEX Plan dedicates 25 percent of the revenue to rebates for low-income and rural households and 75 percent of the revenue for electricity subsidies to households and businesses.

Table ES-2: Change in Economic Welfare by Household Groups

Economic Welfare Change by Quintile in 2020 (2015$ per household)

	Carbon Price Policy			
	TCI	**WCI**	**ESSEX**	**High Price**
Quintile 1	$53	$96	$37	$414
Quintile 2	$18	$35	$24	$171
Quintile 3	-$18	-$38	$5	-$132
Quintile 4	-$22	-$15	-$46	-$82
Quintile 5	-$122	-$251	-$51	-$1,240
Urban (Chittenden County)	-$13	-$12	$0	-$122
Rural (Weighted average, all other counties)	-$20	-$42	-$8	-$191

- When carbon pricing revenue is used to provide lump-sum rebates (as in the TCI and WCI examples above), the policy raises economic welfare for lower- and middle-income households (i.e., these households are made better off, even ignoring the environmental benefits of the policy), because the rebates (which are a relatively large percentage of income for these households) more than offset the increase in expenditures for energy goods.
- Carbon prices with lump-sum rebates reduce economic welfare for higher-income households because the increase in energy expenditures is greater than the lump-sum rebates (which are relatively small compared to income for these households).
- Rural households are generally worse-off than urban households due to their higher share of energy expenditures, but the difference is not generally substantial. And, to the extent that rural households are also low-income, they may still be made better off (as discussed above).
- Economic welfare impacts are smaller when carbon pricing revenue is used to provide electricity subsidies and reductions in taxes on wage earnings. These impacts tend to be negative for the lowest-income households and positive for the highest-income households: the value of these subsidies or tax reductions is roughly proportional to income, and thus doesn't offset the low-income household's higher share of spending on energy goods. A similar result applies for rural households.
- Hybrid revenue use, such as the ESSEX Plan, can provide both protection to low-income households AND reduce the negative impacts on higher income households.
- Policies that use revenue to finance nonpricing policies such as electric vehicle purchase incentives and clean energy investment should, if well-implemented, further decrease emissions, but would forgo the benefits of returning the revenues through rebates, reductions in other tax rates, or subsidies to electricity rates.[20]

Methodology

To evaluate and compare the ability or potential of alternative carbon pricing policies to achieve reductions in GHG emissions, spur economic development, cause shifts in employment, and affect the cost of living in Vermont, we use a set of models developed by researchers at Resources for the Future (RFF). Using these models, we evaluate how environmental and economic policy outcomes vary by the level of the price, how the revenue is used, the number of sectors covered by the policy, and the geographic scope of the policy. In addition to evaluating the impacts on Vermont's GHG emissions and GSP, we also evaluate how consumer prices and household incomes change, how those changes affect aggregate state welfare, and how the changes are distributed across different household types, with a focus on low-income and rural Vermonters.

Conclusions

Given Vermont's current emissions profile, with emissions concentrated in transportation and heating fuels, decarbonizing the economy to meet the state's goals will not be easy. A quantitative evaluation of a set of carbon pricing policies suggests that a carbon pricing–only decarbonization strategy in Vermont is unlikely to produce the level of GHG emissions reductions required to meet the state's climate targets (unless the carbon price is set substantially higher than levels considered in this study). However, the analysis also demonstrates that the combination of a moderate carbon price (moderate in both price level and sectoral scope) with a comprehensive set of nonpricing approaches could allow the state to meet some, but not all, of its emissions reduction targets (though this combined approach would likely be costlier than achieving the same emissions reductions via a higher carbon price).

Economically, these types of carbon pricing policy approaches are most likely to produce small negative economic impacts ($20–$100 per person, ignoring all environmental benefits from the policy). However, the monetary benefits of reduced carbon dioxide emissions and cleaner local air are expected to exceed these costs. In choosing how to use the revenue raised through a carbon pricing policy, policymakers face trade-offs between environmental outcomes, overall economic costs, and the impacts on different types of households: returning all available revenue to households as rebates is likely to have the largest (though still quite small) overall economic cost but would more than compensate low-income households for higher energy prices, thus making these households better off overall (even when ignoring any environmental benefits); using all available revenue to reduce taxes on wage income may be beneficial to Vermont's economy overall but would impose costs on low-income households; devoting all available revenue to green investments may reduce emissions further but would impose higher costs on all Vermonters, including low-income and rural households, compared to other options that use revenues to partially or fully offset the economic burden imposed on households. In choosing how to use the revenue from a carbon pricing policy, policymakers will need to balance these trade-offs.

1. Introduction

On June 25, 2018, the Vermont legislature passed Act 11, which included provisions to implement five preliminary recommendations to the governor from the Vermont Climate Action Commission.[21] One of those recommendations was to study "regulatory and market decarbonization mechanisms" (VCAC 2017) with the aim of better understanding various policy approaches for reducing greenhouse gas (GHG) emissions in Vermont. This report is the execution of that recommendation and legislative intent.

This study is designed to assist Vermont policymakers and stakeholders in considering policies to reduce greenhouse gas emissions in an economical and environmentally effective manner. It does not issue recommendations, but rather aims to provide unbiased, independent information to best inform the climate policy dialogue in Vermont. Nor is it intended to comprehensively address the complete universe of public policy options for reducing greenhouse gas emissions in Vermont. As requested by the Joint Fiscal Office, this study focuses on a quantitative analysis of carbon pricing policy options,[22] with a limited discussion of nonpricing policies that relies on previous work conducted by the Vermont Climate Action Commission and the Energy Action Network.

This report is divided into six sections. The second section, following this brief introduction, outlines the context for the discussion of policies to reduce GHG emissions in Vermont. The third section outlines a suite of nonpricing policies previously discussed in Vermont and provides a back-of-the envelope quantitative snapshot of the emissions reduction potential of those policies. The fourth section provides results on the quantitative analysis of carbon pricing policies, including analysis of the distribution of costs and benefits among Vermont household income groups. The fifth section offers other observations that are beyond the scope of the modeling analysis. The sixth section concludes.

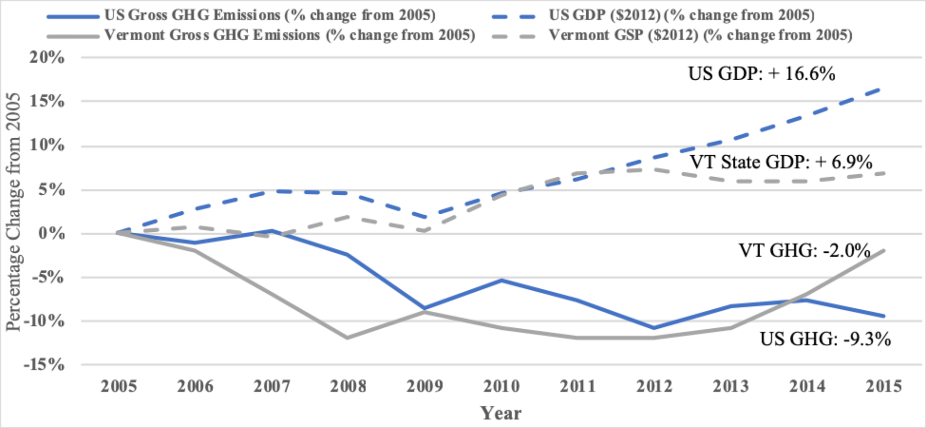
2. Vermont Context

2.1. General Economic and Environmental Trends

In 2015, Vermont gross domestic product (state GDP) was $28.8 billion (in 2012$), up from $26.9 billion in 2005 (in 2012$), an average increase in real state GDP of about 0.7 percent per year between 2005 and 2015.[23] Over the same time span, Vermont's greenhouse gas (GHG) emissions have fallen from about 10.2 million metric tons carbon dioxide equivalent (MMTCO$_2$e) in 2005 to about 10 MMTCO$_2$e in 2015 (VT DEC 2018, Table 1).

Figure 1.1 displays the change in state GDP and US GDP and gross GHG emissions relative to 2005 for Vermont and the United States. In both regions, GHG intensity is declining, as illustrated by the fact that state GDP and national GDP have grown since 2005 and GHG emissions have declined since 2005. This means each dollar of value, on average, has been produced with less pollution over time. These decreases in emissions intensity are likely a combination of market forces (cheap natural gas) and efforts in Vermont and the United States to invest in clean energy and energy efficiency.

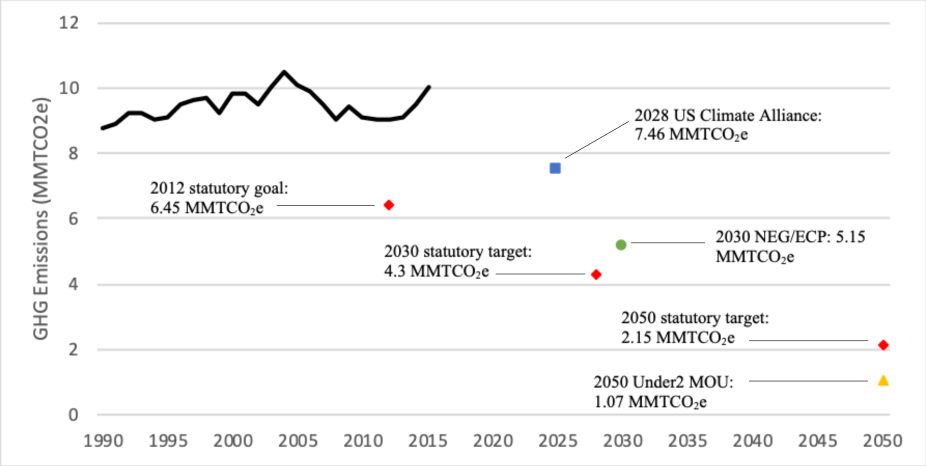
Figure 1.1. US and Vermont GDP and GHG Emissions, 2005–2015, Percentage Change from 2005



Sources: EPA (2018c), VT DEC (2018), Federal Reserve Economic Data, Federal Reserve Bank of St. Louis, **https://fred.stlouisfed.org/series/VTRGSP**, **https://fred.stlouisfed.org/series/GDPCA**.

However, and perhaps most importantly for Vermont policymakers interested in reducing GHG emissions, emissions have been rising since 2011. The recently updated GHG inventory report shows that Vermont not only missed its 2012 GHG target (actual emissions were 12 percent below 2005 levels compared with the target of 37 percent below 2005 levels) but also is not currently on a pathway to achieving its emissions targets, as demonstrated by Figure 1.2 (see the discussion of Vermont climate targets in Section 2.2). In comparison, both national emissions (EPA 2018, Table ES-2) and Massachusetts emissions (MassDEP 2018) declined over the same period that Vermont's emissions have been increasing (2011-2015).

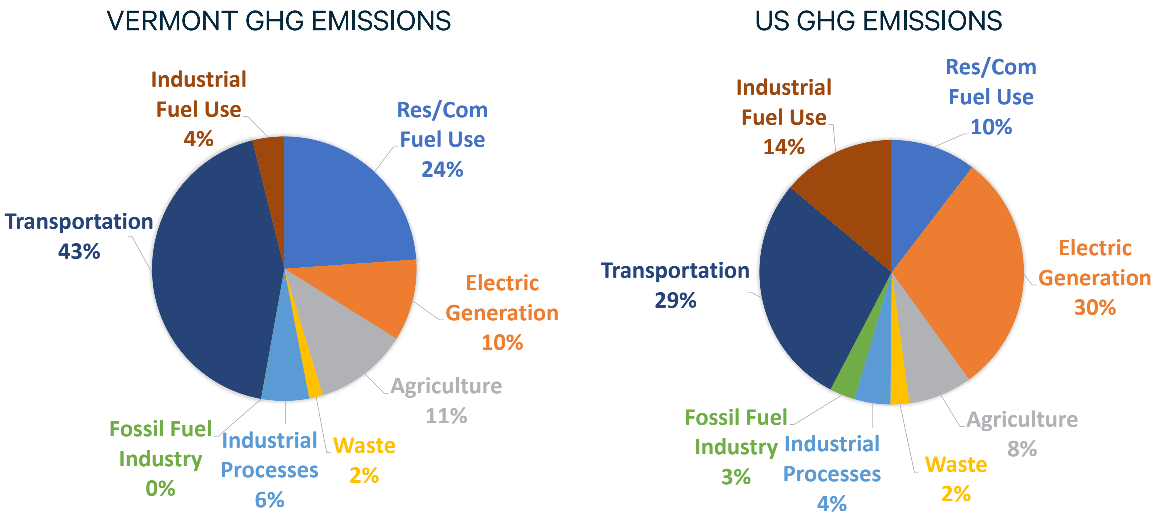
Figure 1.2. Vermont GHG Emissions Trends, 1990–2015



Source: VT DEC (2018).

In 2015, Vermont's GHG intensity, 0.35 $MMTCO_2e$ per billion of state GDP (in 2012$), was comparable to the national rate, 0.38 $MMTCO_2e$ per billion of GDP (in 2012$), but there are substantial differences in the sources of emissions between Vermont and other states. Figure 1.3 displays the differences in where Vermont's and the United States' GHG emissions come from. In Vermont, transportation emissions—the product of gasoline and diesel consumption in cars, trucks, buses, planes, and trains—are the largest source of emissions, at 43 percent of total emissions. In the United States as a whole, transportation emissions are only 28 percent of total emissions. Fuel use in Vermont homes and businesses, primarily for heating ("Res/Com Fuel Use"), is a close second, at 24 percent of total emissions, but fuel use in homes and businesses is only 10 percent of US emissions. And although Vermont uses a consumption-based measure of electric generation emissions that attributes some of the state's electricity use to fossil-based generation outside the state, the share of electric generation emissions is much smaller in Vermont than in the United States.[24]

Figure 1.3. Share of Vermont and US GHG Emissions by Sector, 2015



Source: VT DEC (2018).

The sources of GHG emissions in Vermont present unique challenges to significantly reducing emissions. Vermont has practically zero in-state electric generation emissions, and the electric generation sector is often the most cost-effective sector to decarbonize (Goulder and Hafstead 2017). It is also hard to design policies that incentivize electricity emissions reductions outside state borders. The transportation sector, the largest source of Vermont emissions, is often the most difficult sector to decarbonize (in part because behavior in that sector is not particularly sensitive to changes in fuel prices or nonpricing policies) (Kaufman and Gordon 2018). Heating fuel emissions are also generally difficult to reduce (again, in part because behavior in that sector is relatively price insensitive and nonpricing policies). The fact that a much larger share of Vermont emissions comes from difficult-to-decarbonize sectors than for the United States as a whole also implies that a cost-effective national decarbonization policy would probably reduce Vermont emissions by a much smaller percentage than emissions in other states. As a result, policy prescriptions that apply at the national level may not be appropriate for Vermont, which underscores the need for this Vermont-specific analysis of decarbonization policies.

Finally, the inequality in energy use within Vermont has important implications for how the effects of decarbonization policies will be distributed across households. For example, the average household in South Burlington spent just over 3 percent of its annual income on energy costs, while the average household in St. Albans City spent a full 25 percent of its annual income on energy (Efficiency Vermont 2016). Policymakers need to be aware of these inequalities when designing decarbonization strategies.

2.2. Vermont GHG Emissions Reduction Targets

Vermont is currently party to, or has formally adopted, at least four GHG reduction targets, which are summarized below.[25]

1. Statutory targets.[26] In 2005, Vermont passed state law (10 V.S.A. §578) to reduce GHGs from 2005 levels by the following amounts:

- 37percent by January 1, 2012 (which, as stated above, was not achieved)
- 58 percent by January 1, 2028
- "If practicable using reasonable efforts," 79 percent by January 1, 2050

2. US Climate Alliance targets. In June 2017, Governor Scott announced that Vermont would join the US Climate Alliance, a bipartisan group of states committed to achieving the US goals under the Paris Climate Agreement, a 26–-28 percent reduction of GHGs below 2005 levels by 2025.[27]

3. Under2 MOU.[28] In May 2015, Vermont became a signatory to the Under2 MOU pledge, which includes a target of reducing emissions 83–96 percent below 2005 levels by 2050.

4. NEG/ECP. In August 2015, Vermont joined the conference of New England Governors and Eastern Canadian Premiers (NEG/ECP) in establishing a target of reducing regional GHGs 45–54 percent below 2005 levels by 2030.[29]

Table 2.1. Vermont GHG Emissions Reduction Targets

Target Source	Base Year	Target Year(s)	Reduction from Base Year	Reduction from 2005	Reduction from 2015
VT Statute	1990	2028, 2050	50%, 75%	58%, 79%	57%, 79%
U.S. Climate Alliance	2005	2025	26–28%	26–28%	24–26%
Under2MOU	1990	2050	80–95%	83–96%	83–96%
NEG/ECP	1990	2030	35–45%	45–54%	44–53%

Historical VT Emissions (MMTCO2e)	1990	2005	2015
	8.59	10.22	9.99

In addition to these emissions targets, the **2016 Vermont Comprehensive Energy Plan (CEP)** established the following goals, which would also reduce GHGs considerably:

- Reduce total energy consumption per capita by 15 percent by 2025, and by more than one-third by 2050
- Meet 25 percent of the remaining energy needs from renewable sources by 2025, 40 percent by 2035, and 90 percent by 2050
- Meet these three end-use sector goals for 2025: 10 percent renewable transportation, 30 percent renewable buildings, and 67 percent renewable electric power (VT DPS 2016)

This report focuses on the impacts of decarbonization policies, particularly carbon pricing policies, through the year 2030. Modeling analysis to 2050 features too much uncertainty to be reliable (Barron et al. 2018), and long-term forecasts are beyond the scope of this analysis. In Section 4, we compare the emissions levels from carbon pricing and noncarbon pricing with these various emissions targets, with a particular focus on the US Climate Alliance targets in 2025, as these targets are by far the most achievable, and the state's statutory target for 2028.

2.3. Existing State Actions to Cut Greenhouse Gas Emissions

The state of Vermont has taken a number of steps to reduce greenhouse gas emissions. Below, we summarize some of these activities; however, this is not meant to be an exhaustive list.

2.3.1. Energy Efficiency in Buildings and Facilities

Vermont has been a national leader in innovative policy to advance energy efficiency for many years. In 1999, the Vermont legislature and the Vermont Public Utility Commission created Efficiency Vermont, which provides energy efficiency technical services and financial incentives to Vermont homes and businesses.[30] Efficiency Vermont was one of the first entities to develop a model for bidding energy efficiency resources into the ISO New England Forward Capacity Market, an innovation in wholesale electricity markets that has helped boost the financial returns to, and therefore increase investments in, energy efficiency nationwide (ISO New England 2016).

Vermont maintains a strong set of building energy codes (updated in 2015), which require new homes and commercial buildings to be built to the standards set forth in the 2015 International Energy Conservation Code.[31] In addition, Vermont has developed a building energy labeling system to improve the transparency and market value of energy efficient buildings.[32] And the state provides tax incentives to both commercial and residential property owners for energy efficiency investments, as well as loan and loan guarantee programs to lower the cost of investing in energy efficiency.[33]

2.3.2. Transportation

Vermont follows the California emissions standards for light-duty vehicles, which include GHG emissions requirements for traditional internal combustion engine vehicles, as well as the most recent zero emissions vehicle (ZEV) standards. The ZEV standards require that at least 4,500 all-electric or plug-in hybrid vehicles be sold in Vermont by 2025. Vermont is also part of the multistate ZEV MOU, which aims to collaboratively get 3.3 million ZEVs on the road by 2025. Vermont has completed its own ZEV Action Plan, which includes a number of strategies for growing the ZEV market in Vermont, such as providing consumer incentives, increasing the number of ZEVs in state and municipal fleets, and advancing electric vehicle (EV) charging and hydrogen fueling infrastructure throughout the state (VT DPS 2016; VT Climate Cabinet 2014).[34]

Vermont also has promoted the adoption of compact and transit-oriented land use planning to minimize the need for automobile use. This includes statutory provisions that in 2011 strengthened the five-state land use designation programs (VT DPS 2016) and in 2016 created a program to support regional planning commissions in the development of regional energy plans.[35]

Moreover, the state has investigated various policy pathways to increase the quantity of renewable biofuels used in the state. The 2016 CEP, for example, states a goal of meeting 10 percent of statewide transportation fuel demand with renewable resources by 2025. The 2016 CEP also outlines a number of policy pathways for achieving this goal, including the investigation of a regional low-carbon fuel standard similar to what has been implemented in Oregon and California.

2.3.3. Electricity

The Regional Greenhouse Gas Initiative (RGGI) is a cap-and-trade program that covers carbon dioxide emissions from electricity generators in nine states and is soon to be expanded to two more states, New Jersey and Virginia. Vermont has been a participant since the program began in 2009. Electricity generators must hold allowances equal to their annual emissions; allowances are auctioned quarterly. As measured by the market price of tradable emissions allowances, RGGI is a modest program, but over the course of its existence, emissions from the electricity sector in the region have fallen dramatically. Revenue from the auction of allowances accrues to states; Vermont has chosen to spend a majority of the revenue on energy-efficiency programs. RGGI also has a review process and the emissions caps are periodically adjusted.

In addition, in 2015, Vermont passed Act 56, which establishes a renewable energy standard (RES) with the following targets:

- That 55 percent of electricity by 2017 and 75 percent by 2032 come from renewable sources (Tier 1)
- That 1 percent of electricity by 2017, rising to 10 percent by 2032, come from small (less than 5 megawatt [MW]) distributed renewable sources (Tier 2)
- That 2 percent of electricity by 2017, rising to 12 percent by 2032, come from “energy transformation” projects—a category that encompasses further distributed renewable generation and projects that reduce utility customers’ fossil fuel use more broadly, including electric vehicle charging stations and heat pumps (Tier 3) (VT DPS 2016)

Vermont’s net-metering program was established in 1999 and received updates in the legislature in 2012 and 2014 (VT DPS 2016).[36] The program provides incentives to homeowners and businesses to invest in renewable energy installations, such as rooftop solar, by allowing them to sell any surplus electricity they generate back to the utility (at retail prices). Vermont’s standard offer program and clean energy facility siting policy have also supported the development of renewable energy resources across the state (VT DPS 2016).

2.4. Legislative Efforts

The Vermont legislature has considered a number of policies in recent years to further advance decarbonization. Below is a list of just some of the recent proposals to reduce emissions through carbon pricing (all proposed during the 2017-2018 biennial session).

- *H.791 (ESSEX Plan)*

  This bill proposed to adopt a charge on the carbon content of fossil fuels and return all revenues to customers on their electric bills. The carbon fee would start at $5 per metric ton of carbon content, rising by $5 per metric ton for seven years until reaching $40 per metric.

  Revenues would be allocated to each of three sectors (residential, commercial, and industrial) based on the estimated percentage contribution of each sector’s total revenues. Revenues would be rebated to commercial and industrial customers equally according to their electricity consumption ($/kWh) and to residential customers as follows:

  - 50 percent of revenues would be a “general” rebate, divided equally among all residential customers
  - 25 percent of revenues would be dedicated to rural customers
  - 25 percent of revenues would be dedicated to low- and middle-income customers

- *H.528*

  This bill proposes to do the following:

  - Double the amount of earned income tax credit available under 13 32 V.S.A. § 5828b
  - Lower the personal income tax rate for Vermont's lowest income tax bracket from 3.55 to 1.75 percent
  - Exempt businesses earning less than $400,000 from Vermont's corporate income tax
  - Charge corporations a fee for distributing fossil fuels that emit carbon pollution to make the remaining changes in the bill revenue neutral
  - Exempt nonprofit organizations and municipalities from the fee imposed on corporations that distribute fossil fuels that emit carbon pollution

- *H.531*

  This bill proposes to establish a carbon pollution fee that starts at $10 per ton and increases each year until it equals the social cost of carbon (SCC). This bill would return all revenue collected from individuals to individuals on an equal and quarterly basis in the form of dividend checks or direct deposits and would return revenue collected from businesses in the same manner.

- *H.532*

  This bill proposes to decrease statewide education property tax rates by replacing Education Fund revenue raised through property taxes with revenue raised through a fee on carbon dioxide pollution. The rate reduction and replacement of revenue would be done on a revenue-neutral basis. *No price level is included in the "short form" bill.*

- *H.533*
  This bill proposes to eliminate Vermont's sales and use tax by reducing the tax by 1 percent each year for six years. At the same time, a fee would be imposed on fossil fuels. The fee would increase over a six-year period to replace the revenue forgone from the elimination of the sales and use tax, in a revenue-neutral manner. Nonprofits and municipalities would be exempt from the carbon fee. *No price level is included in the "short form" bill.*

3. Nonpricing Policy Options

3.1. Nonpricing Policy Background

As discussed in Section 2, Vermont has implemented a range of policies that reduce greenhouse gas emissions. These include financial incentives (e.g., clean energy tax credits or deductions, energy efficiency rebates), performance mandates (e.g., the renewable energy standard, the ZEV mandate, building codes), governmental practices (e.g., green procurement practices in state and local government, municipal energy efficiency retrofits), land use planning, energy facility siting policies, and public education. This report refers to this group of policies as *nonpricing* policies.

Nonpricing policies are generally limited to a specific sector (e.g., transportation) or in some cases a specific technology (e.g., heat pumps). While this type of policy strategy can be effective at achieving specific technology-adoption aims, most environmental economists generally consider nonpricing policies to be a less efficient or cost-effective way to decarbonize compared with economy-wide policies that create uniform price signals, such as carbon pricing.

3.2. Evaluating Nonpricing Options

The scope of work for this project, as developed with the Joint Fiscal Office, includes only limited "qualitative" discussion of nonpricing policies. As such, it is beyond the scope of this project to conduct a wholly new quantitative analysis of nonpricing policies. However, in an effort to provide Vermont lawmakers and stakeholders with insight on a comprehensive statewide decarbonization policy framework (which will most likely include nonpricing policies, as is the case in most states and provinces that have adopted carbon pricing as well), Resources for the Future (RFF) has assembled quantitative emissions reduction estimates of a limited set of nonpricing policies, relying largely on the existing work of the Vermont Climate Action Commission and the Energy Action Network.

3.2.1. The Vermont Climate Action Commission Recommendations

In July 2017, Governor Scott issued Executive Order No. 12-17 to create the Vermont Climate Action Commission (VCAC), a committee of 21 representatives from a range of both for-profit and nonprofit organizations and various state, regional, and local government agencies. The governor directed the commission to "draft and recommend, for the Governor's consideration, an action plan aimed at reaching the State's renewable energy and greenhouse gas reduction goals while driving economic growth, setting Vermonters on a path to affordability, and ensuring effective energy transition options exist for all Vermonters." [37] After releasing preliminary recommendations in December 2017, the VCAC issued its final recommendation report to the governor in July 2018. This report includes over 50 specific policy recommendations across the following five areas:

1. “Homes and Workplaces”: policies related to reducing and decarbonizing energy use in residential and commercial buildings, including the promotion of energy efficiency and advanced wood heat technology
2. “Getting Around”: policies related to decarbonizing transportation, including measures to promote the adoption of electric vehicles and improve public transit
3. “Communities and Landscapes”: policies related to land use planning, land conservation, and forest stewardship practices
4. “Sequestering Carbon on Vermont’s Farms and in Its Forests”: policies related to carbon sequestration in and on Vermont forests and farms
5. “Jobs and the Economy”: policies that support clean energy entrepreneurs and that invest in grid modernization and technology innovation (VCAC 2018)

3.2.2. VCAC Estimates of Emissions Reduction Potential

The VCAC estimated emissions reductions for many—but not all—of the policy recommendations included in the 2018 report. In some cases, the commission produced emissions estimates for a group of policies (instead of individually), such as the set of recommendations for electrifying light-duty vehicles.

The commission uses the following four-tier scale to categorize policies by their estimated annual emissions reduction impact (by 2025):

- *High impact*: more than 0.484 million metric tons CO_2e ($MMTCO_2e$)
- *Moderate impact*: between 0.242 and 0.484 $MMTCO_2e$
- *Low impact*: between 0.121 and 0.242 $MMTCO_2e$
- *Lowest impact*: less than 0.121 $MMTCO_2e$ (VCAC 2018)

Below, we summarize the VCAC figures for all policies that received an emissions reduction estimate. Policies in the “Communities and Landscapes” and “Jobs and the Economy” categories did not receive emissions reduction estimates, which is why those categories are omitted from the tables below.

Overall, the VCAC report estimates that nonpricing policies would reduce Vermont’s annual emissions by 8 to 29 percent by 2025, relative to 2005 emissions levels, with the largest reductions coming from energy efficiency and clean energy improvements in residential and commercial buildings and from decarbonizing transportation, as shown in Table 3.1. When this is combined with our estimates for emissions in the absence of policy, emissions are projected to be 19–40 percent below 2005 levels in 2025. However, substantial additional research and policy deliberation is necessary to determine both the specific policies to deliver these reductions and the full environmental and economic impacts of those policies.[38]

3.2.3. Emissions Reductions from Increasing the Stringency of the Renewable Energy Standard

In addition to estimating GHG reductions associated with policies recommended by the VCAC, we conduct a back-of-the-envelope calculation to approximate emissions reductions that could come from increasing the stringency of Vermont's Renewable Energy Standard (RES).[39] The RES, which sets target shares of electricity generation from different renewable sources and more, is a cornerstone of Vermont's existing decarbonization policy package, as mentioned in Section 2 above. Vermont is one of 29 states and the District of Columbia (DC) with such a policy, and it is estimated that over half of US renewable energy growth since 2000 is associated with such policies (Barbose 2018). Various jurisdictions are rapidly increasing their RES policies—for example, in December 2018, the District of Columbia passed a policy to require its utilities to provide 100 percent renewable electricity by the year 2032.

For purposes of estimating the potential of nonpricing policies in Vermont, we consider a range of RES-increase scenarios, from (a) no change from current policy to (b) 100 percent renewable energy by 2030.[40] To estimate 2025 emissions reductions associated with this policy, we begin by assuming a RES requirement of 60 percent in 2020 (the current RES requires 59 percent by 2020—we rounded to 60 percent to simplify). We then assume the required share of renewable energy grows by four percentage points each year, reaching 100 percent in 2030. Therefore, in 2025, the upper-bound RES scenario would require 80 percent renewable electricity.

Business as usual (BAU) estimates of electricity emissions are 0.7 $MMTCO_2e$ in 2025 and 0.6 in 2030 (see Table 3.1 below). Annual emissions reduction estimates from the upper-bound RES scenarios would be 0.56 $MMTCO_2e$ in 2025 (80 percent of 0.7 $MMTCO_2e$) and 0.60 $MMTCO_2e$ in 2030 (100 percent of 0.6 $MMTCO_2e$). Table 3.1 summarizes the range of expected emissions reductions estimates for 2025 (the RES scenarios are embedded in the Electricity sector estimates).

Table 3.1. Annual Vermont GHG Emissions under Nonpricing Policies, by 2025

	Million Metric Tons CO2 Equivalent (MMTCO2e)			
		Nonpricing Policy Scenario		
Sector	BAU	Low-End of Range	High-End of Range	Median
Electricity (consumption based)	0.7	0.7	0.1	0.4
Residential and Commercial Buildings	2.5	2.1	1.3	1.7
Transportation	4.0	3.6	3.2	3.4
Fossil Fuel Industry	0.0	0.0	0.0	0.0
Industrial Processes	0.6	0.6	0.6	0.6
Waste Management	0.2	0.2	0.2	0.2
Agriculture	1.1	1.0	0.7	0.4
Total	**9.1**	**8.2**	**6.0**	**6.7**
Total Relative to 2005	**-11%**	**-19%**	**-41%**	**-34%**

3.2.4. Summary of VCAC Recommendations by Sector

Below, we briefly list the individual policy recommendations included in the VCAC total sectoral estimates reported in Table 3.1. Only policy recommendations that had singular emissions estimates or were part of a group estimate are included in the list below.[41]

Residential and Commercial Buildings. The following nonpricing policies related to residential and commercial buildings were included in the estimates reported in Tables 3.1:

- Double low-income weatherization through the State Weatherization Assistance Program
- Accelerate the adoption of advanced wood heat (AWH) to replace high-GHG-emitting systems to reach 30 percent of Vermont thermal needs by 2025 (triple the number of installations)
- Accelerate building electrification (install 60,000 space and water heat pumps by 2025)
- Adopt and implement a roadmap for all new buildings to be net zero by 2030
- Increase building energy labeling in Vermont to make building energy use more visible
- Increase the number of low- to moderate-income homes weatherized through the Energy Efficiency Utility program

Transportation. The following transportation nonpricing policies were included in the estimates displayed in Tables 3.1:

<u>Light-Duty Vehicle Policies</u>

- Provide a state-funded or state-facilitated EV purchase incentive that applies to new and used EVs, including potential use of Volkswagen (VW) settlement funds for this purpose (subject to limitations)[42]
- Strengthen the used EV market
- Make special EV pricing purchase and lease deals more visible and available to the public by consolidating and continually updating information from EV dealerships
- Implement recommendations in the Vermont Agency of Transportation's corridor study to provide direct current fast charging within 30 miles of all Vermonters
- Develop and execute strategy for deployment of VW settlement funds for EV charging (subject to limitations)
- Conduct research and analysis needed to support the PUC workshop on issues relating to the charging of plug-in EVs required by Vermont Act 158 of 2018
- Leverage and enhance Drive Electric Vermont (DEV) to maximize the impact of education and outreach campaigns and stakeholder engagement to build awareness and encourage purchase consideration for EVs

- Implement “ride and drive” events to give Vermonters a chance to test drive or experience EVs in person and support purchase consideration for EVs
- Work collaboratively with auto dealers on developing and deploying strategies to effectively engage customers who are interested in purchasing an EV and to make the sale
- Make EVs available through traditional car rental, car share, taxi, or ride-hailing service to provide drivers ready access to an EV at low cost and with no ownership or lease commitment

Heavy-Duty Vehicle Policies

- Use VW settlement funds to jump-start a transition from diesel to electric transit and school buses (subject to limitations)
- Investigate and use grant funding and finance strategies to help overcome the high up-front costs of electric transit buses

Transportation Mode Shifting Policies

- Increase use of public transit in Vermont with more public transit infrastructure, trip planning tools, and enhanced service with more efficient vehicles and routes
- Increase efficiency of school transportation, and promote active transportation to school
- Increase programs and public infrastructure to support walking and biking in Vermont
- Implement programs and policies to increase multimodal transportation
- Improve infrastructure to support safe and efficient multimodal travel

Agriculture and Forest Carbon Sequestration. The following carbon sequestration nonpricing policies were included in the estimates shown in Tables 3.1:

- Document goals and mitigation contributions from agricultural sequestration, and create a best-practice guide for farmers
- Investigate opportunities for the sale of carbon offsets and other mechanisms that leverage private finance
- Develop an accurate baseline of carbon sequestration in agricultural soils
- Design and implement a way to track the sequestration benefits of water quality practices; determine levels of adoption and additional, voluntary practices
- Develop and use consistent messaging to farmers about the carbon-capturing cobenefits of the water quality improvements, including the cost-benefit to the farmer
- Use the new BMP Challenge program as an opportunity to evaluate incorporating sequestration into water quality project prioritization and tracking

- Expand state initiatives for urban forestry
- Continue funding the Vermont Housing and Conservation Board for conservation easement purchases on forestland; prioritize projects that emphasize aggregation to maximize conservation and set the stage for carbon offset projects
- Ensure long-term funding for water quality improvements that also sequester carbon and lessen or avoid flood impacts

3.2.5. Economic Impacts of Nonpricing Policies

As indicated above, modeling the economic and fiscal impacts of nonpricing policies is beyond the scope of this study, however important. Below we offer a few qualitative statements relative to the potential economic impacts of nonpricing policies.

- Our analysis does not quantify the climate and health benefits associated with the implementation of nonpricing policies. Both climate and health benefits could be large for such policies.[43]
- In 2017, the California Air Resources Board forecast that a policy that "relies on prescriptive measures to achieve the SB32 target and does not include any carbon pricing mechanism" would result in costs that were 16.4 times greater than the proposed plan that included a cap-and-trade program (CARB 2017).
- We have not modeled labor market effects of nonpricing policies. These policies could theoretically increase local employment and wages, for example if they were to invest in infrastructure that boosts labor productivity in Vermont.
- We have not estimated the effect on state GDP of nonpricing policies. Such policies could theoretically increase or decrease state GDP, but there is little empirical evidence on the state-level macroeconomic effects of such policies.
- The distributional impact of nonpricing policies will vary by policy. A 2016 National Bureau of Economic Research conference "Energy Policy Tradeoffs between Economic Efficiency and Distributional Equity" featured a number of papers on the impacts of various nonpricing policies on low-income households. The general pattern of results suggests that reducing emissions via carbon pricing is less regressive than nonpricing policies that would generate similar levels of emissions reductions.[44] (VCAC 2018)

3.3. Evaluating Electric Vehicle Purchase Incentives

As recommended in the VCAC report, Vermont could subsidize plug-in vehicles using carbon price revenue or other sources of revenue, such as funds from the VW settlement agreement that stemmed from the diesel fuel vehicle emissions scandal.[45]

To evaluate the effectiveness of these EV purchase incentives, we use a vehicle choice model developed by RFF researchers to simulate hypothetical rebates to plug-in vehicle consumers. We consider rebates of $1,000, $3,000, and $5,000 that are offered in addition to the federal tax credit of up to $7,500. The subsidy reduces the costs that consumers pay when they obtain a plug-in, and the subsidies increase sales of those vehicles. Because plug-ins emit less CO_2 than gasoline-powered vehicles that would have been purchased otherwise, the subsidy also reduces CO_2 emissions.

We summarize the main results here.[46] According to the model, the $1,000 subsidy raises state-wide plug-in sales by about 20 units, or 10 percent of predicted sales without a subsidy. The higher subsidies would increase plug-in sales more than proportionately, so that a subsidy of $5,000 would increase sales by about 170 units. Cost effectiveness is similar across the subsidy levels we consider: the subsidies reduce CO_2 emissions at a fiscal cost of roughly $200 per ton of CO_2.[47]

4. Carbon Pricing Policy Options

4.1. Carbon Pricing Background

This section starts by discussing the economic concepts behind carbon pricing, the different kinds of carbon pricing, and why carbon pricing leads to cost-effective emissions reductions. It then goes on to discuss key policy choices that need to be made in designing and implementing a regional carbon pricing system.

4.1.1. The Theory behind Carbon Pricing

The basic economic concept behind carbon pricing goes back to Pigou (1920). When the production or consumption of a good affects someone other than the producer and consumer of that good, that effect is an *externality*. If that effect is beneficial, it is a positive externality; if harmful, it is a negative externality. Pollution is a classic example of a negative externality. For example, when burning coal emits local air pollutants, those pollutants harm everyone breathing the air downwind.

Externalities generally lead to economically inefficient market outcomes. In a free market, the buyer's and seller's decisions consider their own benefits and costs, but not the effects on anyone else (i.e., the externality). This means that in an unregulated free market, there will be too much production and consumption of a good that causes a negative externality; the market effectively ignores the harm caused by that negative externality. In the case of coal externalities, this leads to an inefficiently high quantity of coal being burned.

One way to solve that problem is to impose a tax on the good that causes the negative externality. For example, if burning coal causes air pollution, then one could put a tax on coal. That tax will discourage burning coal, thus pushing the quantity burned down from the inefficiently high free-market level. And if the tax is set equal to the harm from the negative externality, then it pushes emissions down to the economically efficient level (the level where the cost of reducing emissions by one ton exactly equals the reduction in pollution damage from cutting one ton of emissions); in this case, the cost imposed on polluters by the tax on a ton of emissions exactly makes up for the cost they're ignoring in their decisions (the harm to others from that ton of pollution).[48]

In the climate change context, this is the concept behind a carbon tax. Burning fossil fuels emits carbon dioxide, which causes climate change, and the damage caused by a changing climate is a negative externality. Imposing a tax on burning fossil fuels proportionate to the carbon emitted from burning those fuels addresses that externality.

But a carbon tax is not the only way to impose a carbon price. An alternative approach to carbon pricing is a cap-and-trade system. Suppose that the government sets an allowable quantity of carbon emissions (the cap) and auctions off that quantity of carbon emissions allowances, with the requirement that fossil fuel users buy enough allowances to cover the carbon they emit. Just as with the carbon tax, that system imposes a price on carbon emissions and thereby discourages those emissions, but in this case the price per ton of CO_2 emitted is not the carbon tax rate; it is the price per allowance. But the incentive created by a tax rate of $X/ton is the same as the incentive created by requiring allowances that sell for $X/ton: under either system, reducing emissions by one ton means that you pay $X less.

The key difference between these two carbon pricing systems—a carbon tax and carbon cap-and-trade—is in how they accommodate uncertainty about the market response to the carbon price. A carbon tax sets the price (the tax rate), and the market determines the quantity of carbon emissions. A cap-and-trade system sets the emissions quantity (the number of allowances issued), and the market determines the carbon price. If the demand for fossil fuels is higher than expected, for example, a carbon tax will result in higher-than-expected emissions (but no change in the carbon price) whereas a cap-and-trade program will result in higher-than-expected carbon prices (but no change in emissions). Hybrid policy designs combine elements of the two systems, allowing both the carbon price and level of emissions to vary, but with less price variation than cap-and-trade and less emissions variation than a carbon tax.[49]

In textbook economics, either carbon pricing system will be *cost-effective*: that is, either form of carbon pricing will achieve a given level of emissions reductions (from the sectors covered by the carbon price) at the lowest possible cost. These policies are cost-effective because they provide the same incentive for reductions regardless of how those reductions are achieved, and they let consumers or businesses choose the best way to respond to that incentive. For example, consider emissions from home heating. For one homeowner, the most cost-effective way to reduce emissions might be to install a more efficient oil furnace. For another, it might be to add more insulation. For a third, it could be to turn down the thermostat. For a fourth, it could be to install a geothermal heat pump. A carbon price provides the same incentive (per ton of emissions reductions) for any of those choices, thus giving homeowners an incentive to reduce emissions, combined with the flexibility to do whatever is most cost-effective in their particular situation. Nonpricing policies (such as mandates) simply do not provide the same level of flexibility, and as a result, they tend to miss some low-cost emissions reductions.[50] Consequently, nonpricing policies tend to cost more than pricing policies for a given level of emissions reduction. For example, consider the comparison between a carbon price and a mandate that requires the installation of heat pumps in all homes. The mandate would be a more expensive option, per ton of emissions reduced, because heat pumps would be installed in all homes, including the ones where a more efficient furnace or increased insulation is a more cost-effective option.

Policymakers may have multiple objectives in designing decarbonization policies, including not just cost-effectiveness but also environmental effectiveness, fairness, political feasibility, and others. Important tradeoffs may exist between these objectives. An additional benefit of carbon pricing policies relative to nonpricing policies is the revenue raised from the policy. As we will discuss below, this revenue provides an opportunity for policymakers to balance these different trade-offs as they see fit.

4.1.2. Key Dimensions of Carbon Pricing Policy Design

Here we discuss key decisions that need to be made in designing and implementing a regional carbon pricing system (whether the carbon price takes the form of a carbon tax or carbon cap-and-trade).

Price Path. The first and most obvious design issue for a carbon price is the price path: how high the price should start and how that price should change over time. The higher the price, all else equal, the larger the effects of the policy will be: a higher price implies larger emissions reductions but also corresponding larger costs, larger effects on the economy and on household budgets, and likely larger carbon pricing revenue.[51] In the case of the cap-and-trade system, regulators can set the price in expectation by setting allowances at a level consistent with a particular price. Regulators can also set price floors or price ceilings to limit price uncertainty. In this study, we consider a range of different price paths, chosen to provide a representative sample of potential carbon pricing policies for Vermont.

Revenue Recycling. A carbon price will raise a substantial amount of revenue.[52] How that revenue is used can substantially influence the effect of the policy on the overall economy, as well as how the cost of the policy is distributed across households. In this study, we model three different potential ways to use the carbon pricing revenue: financing equal per household lump-sum rebates (sometimes referred to as “carbon dividends”), cuts in taxes on labor income, and subsidies for electricity. We also provide a qualitative discussion of using the revenue for “green investment” (investments that will lower emissions).

Sectoral Coverage/Scope. Another key dimension of carbon pricing policy is what emitting sectors are covered by the carbon price. Holding all other dimensions of the policy equal, broader coverage will mean larger emissions reductions but also larger effects on the economy and on household budgets. For a given level of total emissions reductions, it will generally be more cost-effective to have broader coverage (including more sectors of the economy) and a lower carbon price rather than narrower coverage and a higher carbon price: broader coverage at a relatively low price provides an incentive for low-cost emissions reductions in every sector, whereas narrow coverage at a high price means pursuing relatively high-cost emissions reductions in the covered sectors while passing up lower-cost reductions in sectors that are left out.

In this study, we model three sectoral coverage options: covering the entire economy (except electricity, which is already covered by RGGI), covering only transportation and heating fuels, and covering transportation only.

Geographic/Regional Scope. The final policy dimension we focus on is the geographic scope. Here we model two options: a carbon price policy covering just Vermont and one that covers all of New England. If the price applies only to emissions within Vermont, one might worry that production in carbon-intensive industries could shift outside the state, reducing emissions within the state (thus avoiding the carbon price) and imposing costs on the Vermont economy, but not reducing emissions overall ("carbon leakage"). Broader geographic scope for the carbon price reduces the potential for that kind of carbon leakage.

4.2. Evaluating Carbon Pricing Options

4.2.1. Model Descriptions

To evaluate carbon pricing options in Vermont, we use two economic models: the RFF dynamic regional computable general equilibrium (RFF-DR CGE) model and the RFF incidence model.[53] The RFF-DR CGE model is a multiregion and multi-industry intertemporal model of the US economy with international trade. For each policy scenario, the model calculates the changes in the supply and demand of producer and consumer goods by households and firms in each region and the corresponding changes in market-clearing prices. The model is benchmarked to 2015 data, the last year in which all necessary regional data are available. The model is solved annually, with a focus on results through 2030.

The RFF incidence model is employed to analyze the distributional impacts of each policy scenario across income groups and geographic locations within Vermont. Using information on aggregate price and expenditure changes within Vermont from the RFF-DR CGE model, the RFF incidence model approximates the changes in economic welfare stemming from changes in prices and changes in income for households in each income quintile and each region of Vermont.

4.2.2. Metrics for Policy Evaluation

In the following sections, we evaluate the environmental and economic impacts of carbon pricing options relative to business as usual using the RFF-DR CGE model across a variety of metrics. A list of these metrics, along with a short explanation of each metric's importance, appears below.

GHG Emissions Levels. The primary purpose of carbon pricing policies is to reduce energy-related carbon dioxide and other greenhouse gas emissions. The reduction in greenhouse gas emissions relative to business as usual (i.e., no additional GHG policy) measures the environmental effectiveness of the carbon pricing policy.

We measure both the change in emissions in Vermont and the change in (energy-related CO_2) emissions in the rest of the Northeast.

Emissions Leakage

Emissions leakage captures the change in emissions in neighboring states caused by Vermont's decarbonization policy. Emissions leakage is positive if neighboring emissions increase and negative if neighboring emissions decrease. If leakage is large and positive, then this implies that much of the environmental benefits from reduced emissions in Vermont are offset by increased emissions in nearby states. Examples of emissions leakage include increases in fossil-based electricity generation in neighboring states and shifts in production from Vermont to its neighbors. Purchases of fossil fuels out of state and then consumed in state, as would be the case if Vermonters purchase gasoline in neighboring New Hampshire, are not an example of leakage. These emissions are attributed to Vermont regardless of where the gasoline was purchased.

Criteria Air Pollutants. Burning fossil fuels to produce energy produces local criteria air pollutants such as nitrogen oxide (NO_x), ammonia (NH_3), carbon monoxide (CO), sulfur dioxide (SO_2), particulate matter (PM_{10} and $PM_{2.5}$), and volatile organic compounds (VOCs) that harm human health. Because carbon pricing reduces fossil fuel use, it will also reduce emissions of these criteria air pollutants. The RFF-DR models only emissions of these pollutants, not ambient concentrations in the air. Those ambient concentrations primarily determine the health impacts.[54]

Gross Carbon Revenues. Carbon pricing policies (except for cap-and-trade programs with free allocation of allowances) raise revenues that can be allocated in a variety of ways, as discussed above.

Macroeconomic Impacts. Through changes in the relative prices of goods and services, the carbon price will affect both consumption and investment decisions in Vermont. These changes will be reflected in changes in the inflation-adjusted state gross domestic product (GDP), a measure of real economic activity in the state.

Labor Demand Impacts. The carbon price will reduce demand for labor in carbon-intensive industries. In a competitive labor market, this demand reduction will reduce real wages across all sectors of the economy. Non-carbon-intensive industries may increase labor demand as a result of the policy.[55]

Consumer Prices. Carbon pricing policies change the relative prices of goods and services, increasing the prices of carbon-intensive goods relative to non-carbon-intensive goods and services. How much this change in prices will affect the cost of living and consumer welfare will depend on the extent to which consumers can substitute away from carbon-intensive goods to non-carbon-intensive goods; the easier it is to substitute away from a good, the less a price increase for that good will increase the overall cost of living and reduce consumer welfare.

Aggregate Household Income. A carbon price will affect the supply and demand of capital and labor in Vermont. Impacts on aggregate labor and capital income reflect changes in both the average returns to capital and labor and the supply of labor and capital by households in Vermont. Aggregate welfare impacts combine changes in the prices of consumer goods and the change in aggregate household incomes into a single measure of economic well-being.

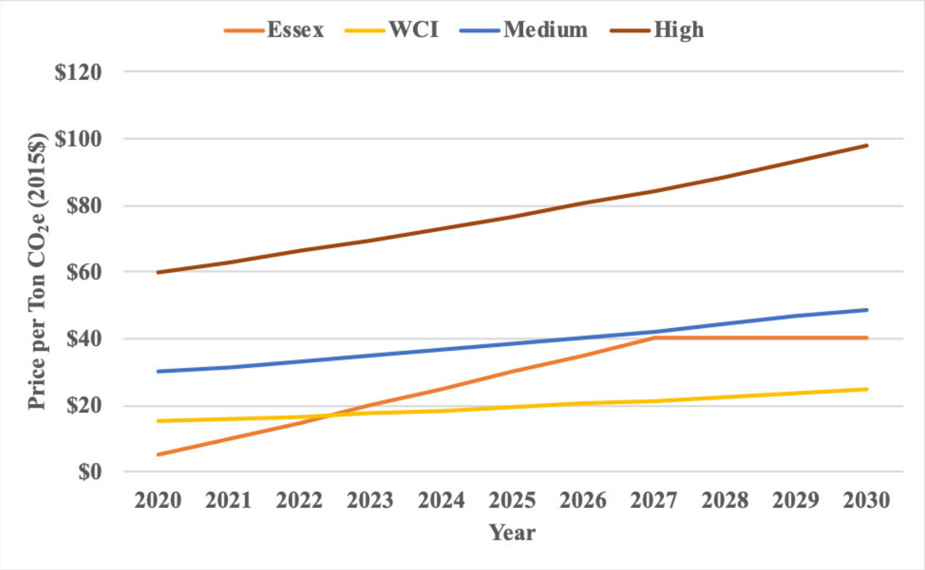
Change in Economic Welfare and Net Benefits. Economic welfare measures the total economic impact of changes in consumer prices and household income in Vermont, excluding the environmental benefits of the policy. Negative changes indicate the average Vermont household is worse-off from the policy; positive changes indicate the average household is better off from the policy. To measure the environmental benefits, we estimate the value of reductions in greenhouse gas emissions and criteria air pollutant emissions. Changes in economic welfare and environmental benefits are combined to determine a policy's total net benefits.

Distributional Impacts. The change in economic welfare will not be evenly distributed across individual households in Vermont. Households that rely on income from carbon-intensive industries will have income impacts that are larger in magnitude than the average impact on household income; households that consume a larger amount of fossil fuels (relative to overall consumption) will have larger cost of living impacts compared with the average household impact. In Vermont, low-income households and rural households have higher energy expenditure shares than high-income and urban households and thus will be more affected by increases in energy prices, though that effect can be offset by the use of revenue from the carbon price.

4.3. Carbon Price Paths

To evaluate how the impacts of Vermont carbon pricing policies vary with the level of the carbon price, we evaluate four different carbon price paths.[56] We assume that all policies are implemented in 2020. The policies differ in the initial price and the change in the price over time. The price paths were chosen to be a representative sample of alternative pricing policies in the state of Vermont. Figure 4.1 displays the carbon price paths over time.

Figure 4.1. Four Alternative Carbon Price Paths, 2020–2030



- *ESSEX Price Path*. The ESSEX Plan (H.791) specifies a $5 per ton carbon tax, rising at $5 each year until the price reaches $40 and stays constant (in 2015$) thereafter.
- *WCI Price Path*. The minimum price for allowances in the Western Climate Initiative (WCI) is projected to be $15.22 (in 2015$) in 2020. Under WCI rules, the minimum price grows at a rate of 5 percent (above the rate of inflation) annually. This implies a minimum price of $19.43 in 2025 and $24.79 in 2030 (both in 2015$). We model this allowance price as a tax on entities required to submit allowance permits.[57]
- *Medium Price Path*. The medium carbon price starts at $30 (in 2015$) in 2020 and grows at 5 percent above the rate of inflation annually. The price reaches $38.29 in 2025 and $48.87 in 2030 (both in 2015$).
- *High Price Path*. The high carbon price starts at $60 (in 2015$) in 2020 and grows at 5 percent above the rate of inflation annually. The price reaches $76.58 in 2025 and $97.73 in 2030 (both in 2015$).

For each carbon price path, we hold fixed the revenue use, the sectoral coverage, and the regional coverage options of the policy to apply equivalent comparisons across different price levels: revenue use is rebated to households via lump-sum rebates; the policy covers carbon dioxide emissions from the transportation, residential, commercial, and industrial sectors ("economy-wide electricity exempt"); and the policy covers Vermont's emissions only. Note: in this section, "ESSEX" and "WCI" represent the carbon price paths associated with those policies and do not represent the full ESSEX Plan or WCI cap-and-trade program with either different revenue use or sectoral coverage. Results for the full ESSEX Plan and WCI policies are included in Section 4.7.

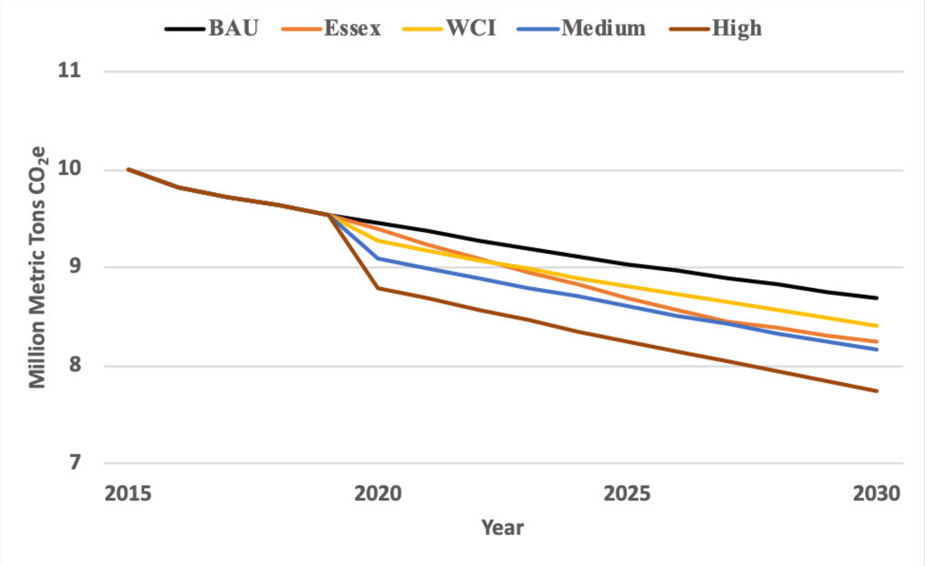
4.3.1. Environmental Impacts

GHG Emissions Levels. Figure 4.2 displays historical and projected greenhouse gas emissions for the state of Vermont from 2015 to 2030 under business as usual (BAU) and the four carbon pricing policies.

Projecting Vermont's Business-as-Usual GHG Emissions

Greenhouse gas emissions by sector are benchmarked to 2015 levels in Vermont's GHG Emissions Inventory (VT DEC 2018). Using the EIA's *Annual Energy Outlook* (AEO) 2018 forecasts for carbon dioxide emissions by sector, we project changes to electricity (consumption based), residential/commercial/industrial fuel use, and transportation emissions under current policies (EIA 2018a). Finally, we assume emissions from the fossil fuel industry (methane emissions from natural gas transmissions and distribution), industrial processes, waste management, and agriculture to be flat between 2015 and 2030. Under these assumptions, Vermont's GHG emissions are forecast to fall from 10 MMTCO$_2$e in 2015 to 9.1 MMTCO$_2$e in 2025 and 8.7 MMTCO$_2$e in 2030 in the absence of new decarbonization policies.

Figure 4.2. Vermont GHG Emissions by Carbon Price Path (Carbon Pricing Only)



The four carbon pricing policies are projected to produce small to modest reductions in Vermont's GHG emissions through 2030 relative to BAU emissions. Under the WCI price scenario, the least aggressive price scenario, emissions are projected to fall only 2.5 percent relative to BAU in 2025 (8.8 MMTCO$_2$e vs. 9.1

$MMTCO_2e$) and 3.3 percent in 2030 (8.4 $MMTCO_2e$ vs. 8.7 $MMTCO_2e$). Under the most aggressive price scenario, emissions are projected to be 8.8 percent lower than BAU in 2025 and 10.8 percent lower than BAU in 2030. The difference between emissions under the WCI and high scenarios reflect increasing marginal abatement costs in Vermont: the high price is nearly four times greater than the WCI price, but emissions reductions (as a percentage of BAU) are less than four times greater.

Table 4.1 displays emissions projections by sector in 2025 and 2030. Vermont's emissions are primarily composed of transportation and heating fuel (residential and commercial) emissions. These two sources of emissions are relatively insensitive to the carbon price: the change in emissions given a change in the carbon price is relatively low. As a result, carbon pricing reduces emissions in Vermont by much less than it would in states with relatively more elastic sources of emissions (such as those with significant electricity generation from coal). Compared to 2005 emissions levels, the WCI price path results in emissions that are 14 percent below 2005 levels in 2025 and the high price path results in emissions that are 19 percent below 2005 levels, well below the US Climate Alliance target of 26-28 percent 2005 levels by 2025. As we discuss below, the relatively modest levels of emissions reductions do not mean these policies are inefficient—they all produce benefits greater than their costs—but they do mean that Vermont's decarbonization goals are too ambitious to be met via these levels of carbon pricing alone. In Section 4.8, we discuss how pricing and nonpricing policy approaches could be combined to meet Vermont's decarbonization goals.

Table 4.1. Vermont GHG Emissions by Sector by Carbon Price Path (Carbon Pricing Only)

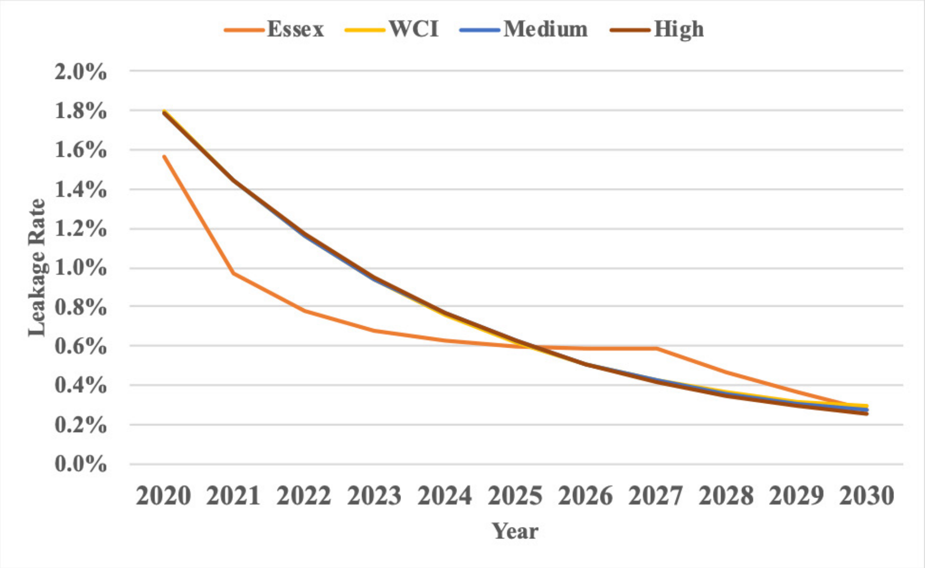
Million Metric Tons CO2 Equivalent (MMTCO2e)											
	2015	2025					2030				
	Historical		Carbon Price Path					Carbon Price Path			
Sector		BAU	ESSEX	WCI	Medium	High	BAU	ESSEX	WCI	Medium	High
Electricity (consumption based)	1.0	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6
Residential/Commercial/ Industrial Fuel Use	2.8	2.5	2.3	2.4	2.3	2.2	2.4	2.2	2.3	2.2	2.0
Transportation	4.3	4.0	3.8	3.8	3.7	3.5	3.8	3.5	3.6	3.5	3.2
Fossil Fuel Industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial Processes	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Waste Management	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Agriculture	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Total	**10.0**	**9.1**	**8.7**	**8.8**	**8.6**	**8.2**	**8.7**	**8.2**	**8.4**	**8.2**	**7.7**
Total Relative to 1990	**16%**	**6%**	**1%**	**3%**	**0%**	**-4%**	**1%**	**-4%**	**-2%**	**-5%**	**-10%**
Total Relative to 2005	**-2%**	**-11%**	**-15%**	**-14%**	**-16%**	**-19%**	**-15%**	**-19%**	**-18%**	**-20%**	**-24%**

Note: Carbon pricing design: lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Fossil fuel industry emissions in Table 4.1 represent Vermont's methane emissions associated with the transportation and distribution of natural gas. In 2015, these emissions were 0.005 MMTCO$_2$e. As displayed in Table 4.4 below, demand for natural gas heating is projected to decline and we project similar decreases in the associated methane emissions from transportation and distribution. Due to the low levels of emissions in 2015, the absolute change in methane emissions is economically insignificant. Agriculture emissions in Table 4.1 represent emissions from enteric fermentation, manure management, and agricultural soils. As with industrial processes and waste management emissions, we assume these emissions are independent of the carbon price.

Figure 4.3 displays the leakage rate to the Northeast states for carbon dioxide emissions.[58] As discussed above, leakage is defined as the change in emissions in neighboring regions divided by Vermont's emissions reductions. The rates of leakage are relatively small across all four pricing paths. The initial rates of leakage are approximately 1.8 percent or less in 2020, and the rates fall as capital stocks adjust in each region. And while the rates of leakage are approximately equal, the level of emissions reductions offset by increased emissions in neighboring states is higher under the price paths with larger emissions reductions.

Figure 4.3. Leakage Rate to Northeast States by Carbon Price Path



The low leakage rates may be an artifact of the economic model used to evaluate carbon pricing policies. Region-to-region trade flows are relatively fixed in the RFF-DR CGE model; households and firms do not significantly shift demand from goods produced in regions with carbon pricing to goods produced in regions without carbon pricing. For the Vermont context, this seems like a fair assumption—demand for Vermont's maple syrup is unlikely to change, for example. However, to the extent that trade flows would shift in response to small or moderate carbon prices in Vermont, the model would underestimate the change in emissions in neighboring states.

Finally, as discussed above, cross-state fuel purchases are not considered leakage (these emissions should be attributed to Vermont), but these purchases could undermine the effectiveness of a Vermont-only carbon price. Our modeling assumes that there will not be a significant change in the purchases of gasoline in New Hampshire by Vermont drivers; it is assumed that drivers who purchase gasoline out-of-state will continue to do so and drivers who purchase gasoline in-state will continue to do so. If this assumption is wrong and drivers do change where they fill their tanks, then the model will overestimate the level of emissions reductions.

Criteria Air Pollutants. The reduction in emissions of local criteria air pollutants that negatively impact human health provides an additional source of environmental benefits from carbon pricing policies. Table 4.2 displays the business-as-usual level of Vermont's emissions of these pollutants in 2025 and 2030 and the percent change from those levels under the carbon pricing policies.

Table 4.2. Percentage Changes in Criteria Air Pollutant Emissions by Carbon Price Path

BAU and Historical:1000 tons; Carbon Pricing: Percentage Change from BAU											
	2015	2025					2030				
	Historical		Carbon Price Path					Carbon Price Path			
Criteria Air Pollutant		BAU	ESSEX	WCI	Medium	High	BAU	ESSEX	WCI	Medium	High
Carbon Monoxide (CO)	135.8	122.9	-3.1%	-2.1%	-3.9%	-7.2%	118.3	-4.1%	-2.6%	-4.9%	-8.8%
Nitrogen Oxide (NOx)	15.5	14.1	-5.1%	-3.4%	-6.4%	-11.6%	13.5	-6.7%	-4.3%	-8.0%	-14.2%
Particulate Matter 10 (PM10)	10.3	9.1	-0.5%	-0.3%	-0.7%	-1.2%	8.9	-0.7%	-0.4%	-0.8%	-1.5%
Particulate Matter 2.5 (PM2.5)	9.0	8.0	-0.3%	-0.2%	-0.4%	-0.7%	7.8	-0.4%	-0.3%	-0.5%	-0.9%
Sulfur Dioxide (SO2)	1.4	1.3	-3.4%	-2.3%	-4.3%	-7.8%	1.2	-4.5%	-2.9%	-5.3%	-9.6%
Volatile Organic Compounds (VOC)	19.6	17.7	-2.5%	-1.7%	-3.2%	-5.9%	17.0	-3.3%	-2.1%	-4.0%	-7.3%
Ammonia (NH3)	0.7	0.6	-3.0%	-2.0%	-3.7%	-6.8%	0.6	-3.9%	-2.5%	-4.7%	-8.4%

Nitrogen oxide and sulfur dioxide emissions are projected to be the most sensitive to criteria air pollutants to carbon pricing because they are most heavily associated with the combustion of gasoline and heating oil. Particulate matter emissions, on the other hand, are only indirectly associated with the combustion of gasoline and heating oil and therefore are much less sensitive to emissions pricing.

4.3.2. Economic Impacts

Gross Carbon Revenues. Each of the carbon pricing policies raises significant revenues for the state of Vermont. Table 4.3 displays the level of annual gross carbon revenues in 2020, 2025, and 2030 for the four pricing scenarios. In 2025, the revenues vary from $120.8 million under the WCI price scenario to $433.8 million under the high price scenario (in 2015$). To put these numbers in comparison, in FY 2015, Vermont's income and estate taxes raised $843.9 million, and the consumption and property taxes raised $1,139.2 million and $1,062.1 million, respectively (VT JFO 2017).

Table 4.3. Annual Gross Carbon Revenues by Carbon Price Path

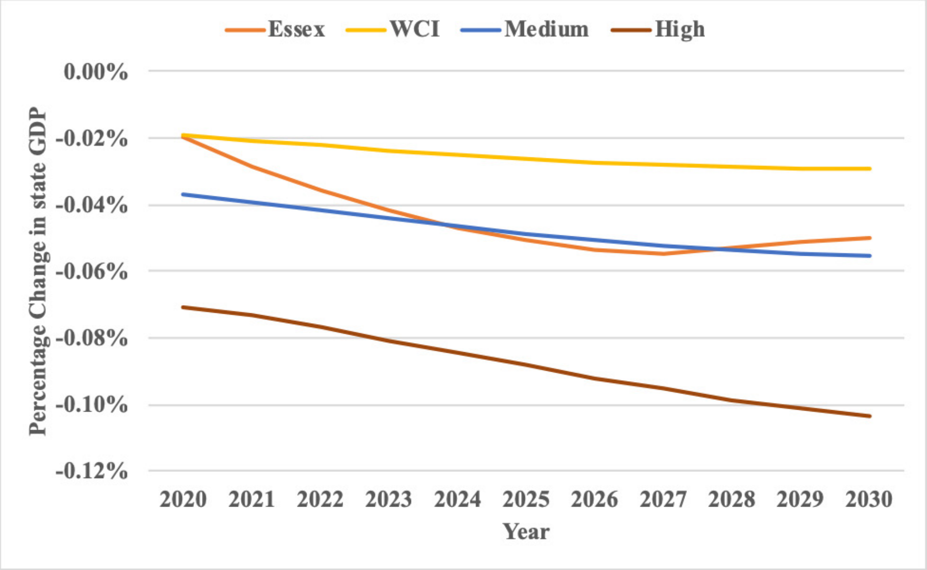
	Millions (2015$)		
Price Path	**2020**	**2025**	**2030**
ESSEX	33.3	183.2	230.9
WCI	99.4	120.8	147.0
Medium	191.0	230.5	278.0
High	364.1	433.8	516.4

Note: Carbon pricing design: lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Macroeconomic Impacts. Figure 4.4 displays the percentage change in Vermont's state GDP. The macroeconomic impacts of the carbon pricing policies, as measured through changes in state GDP, are also small to modest. Note that these changes are relative to business as usual, and thus even with carbon pricing, state GDP will still be growing over time. For example, if in the absence of carbon pricing, state GDP would grow at an annual rate of 1 percent from 2018 to 2025, then the average rate of state GDP growth under these carbon pricing policies would be 0.987–0.997

percent over the same time period, a difference that would be difficult to distinguish from statistical noise. Vermont's state GDP was $30.7 billion in 2015. If one again assumes an average 1 percent business-as-usual state GDP annual growth rate, the reduction in state GDP in 2025 would be $8.9 million under the WCI price scenario and $29.9 million under the high price scenario (in 2015$). Note that these estimates do not include any potential macroeconomic feedback effects from improved local air quality resulting from the policy.

Figure 4.4. Percentage Change in Vermont GDP by Carbon Price Path



The changes in state GDP reflect the average impacts of carbon pricing policies across sectors, but all sectors will not be affected equally. Table 4.4 displays the percentage change in output across Vermont's 14 sectors in 2025 and 2030 in each of the four carbon pricing scenarios. Because Vermont does not produce fossil fuels or other carbon-intensive goods, the impacts of carbon pricing on Vermont industries are relatively small. The negative impacts are concentrated in the carbon-intensive industry natural gas distribution, as the carbon price would limit demand for heating with natural gas. There are also small reductions in other carbon-intensive industries such as transportation. Output rises in some low-carbon-intensity industries; as consumers and businesses shift their spending away from carbon-intensive goods in response to the price increase caused by the tax, they buy more goods from these low-carbon-intensity industries.

Table 4.4. Percentage Change in Industry Output by Carbon Price Path

	2025 Carbon Price Path				2030 Carbon Price Path			
Industry	ESSEX	WCI	Medium	High	ESSEX	WCI	Medium	High
Electricity Generation	-0.2%	-0.1%	-0.2%	-0.4%	-0.2%	-0.2%	-0.3%	-0.5%
Electric Transmission and Distribution	-0.7%	-0.4%	-0.8%	-1.6%	-0.9%	-0.6%	-1.1%	-2.1%
Natural Gas Distribution	-5.6%	-3.8%	-7.1%	-12.9%	-7.9%	-5.1%	-9.4%	-16.6%
Other Mining and Mining Services	-0.1%	0.0%	-0.1%	-0.1%	-0.1%	0.0%	-0.1%	-0.1%
Farms, Forestry, Fishing	-0.2%	-0.1%	-0.3%	-0.5%	-0.3%	-0.2%	-0.3%	-0.6%
Construction	-0.9%	-0.6%	-1.1%	-2.0%	-1.2%	-0.7%	-1.4%	-2.5%
Nondurable Manufacturing	-0.2%	-0.1%	-0.3%	-0.5%	-0.3%	-0.2%	-0.3%	-0.6%
Chemicals, Plastics, Rubber, and Nonmetallic Mineral Products	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Durable Manufacturing	-0.1%	-0.1%	-0.1%	-0.2%	-0.1%	-0.1%	-0.1%	-0.2%
Trade	-0.2%	-0.1%	-0.3%	-0.5%	-0.3%	-0.2%	-0.3%	-0.6%
Transportation	-0.2%	-0.2%	-0.3%	-0.5%	-0.3%	-0.2%	-0.4%	-0.7%
Communication and Information	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%
Services	0.0%	0.0%	0.1%	0.1%	0.1%	0.0%	0.1%	0.2%
Real Estate and Owner-Occupied Housing	0.1%	0.1%	0.2%	0.3%	0.2%	0.1%	0.2%	0.4%
All Industries	**-0.08%**	**-0.05%**	**-0.09%**	**-0.17%**	**-0.10%**	**-0.06%**	**-0.11%**	**-0.20%**

Note: Carbon pricing design: lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Interpreting Model Outputs: Industry

The RFF-DR CGE model uses a representative firm in each industry. For industry variables such as output or labor demand, the results reported from the RFF-DR CGE model represent estimates for changes to that industry in total. However, these representative results mask potentially significant heterogeneity across firms within each industry and do not capture potentially significant lumpy economic impacts such as individual plant or store closings.

Caution should be used when attempting to downscale these industry impacts to either subindustries or individual plants.

As an example, fuel dealers are included in the trade sector (data limitations limit the extent to which we can separate out individual industries), but effects on fuel dealers will probably be more similar to effects on firms in the natural gas distribution industry than to the average firm in the trade sector.

Also, the farms, forestry, and fishing sector represents both agricultural production and the timber industry. While the impacts of carbon pricing on this broad sector are relatively small, we can't project how the policy would impact each sub-sector (agriculture or timber) separately.

Labor Demand Impacts. Employment impacts across sectors, as measured through changes in labor demand, are projected to largely mirror the output impacts across sectors. Table 4.5 reports the percentage change in labor demand across sectors from the modeling analysis. Labor demand declines substantially in the natural gas distribution sector, but the changes are much smaller in other industries. Labor demand increases in communication and information, services, and real estate and owner-occupied housing. Overall, the net change in labor demand in the model is small. In a model that includes a more robust description of the labor market, Hafstead et al. (2018) demonstrate that changes in labor demand overestimate the change in the number of jobs (because some of the change in labor demand is accommodated via changes in hours per worker) and that changes in employment occur through changes in hiring rates as opposed to layoffs. Thus, the reductions in labor demand in some industries should not be interpreted as direct job losses for incumbent workers in those industries; rather, those reductions reflect declines in new hiring in those industries.

Table 4.5. Percentage Change in Labor Demand by Carbon Price Path

	2025				2030			
	Carbon Price Path				Carbon Price Path			
Industry	ESSEX	WCI	Medium	High	ESSEX	WCI	Medium	High
Electricity Generation	-0.3%	-0.2%	-0.4%	-0.7%	-0.3%	-0.2%	-0.4%	-0.8%
Electric Transmission and Distribution	-0.9%	-0.6%	-1.1%	-2.1%	-1.2%	-0.7%	-1.4%	-2.6%
Natural Gas Distribution	-6.5%	-4.3%	-8.1%	-14.7%	-8.5%	-5.5%	-10.1%	-17.7%
Other Mining and Mining Services	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%
Farms, Forestry, Fishing	-0.2%	-0.2%	-0.3%	-0.5%	-0.3%	-0.2%	-0.3%	-0.6%
Construction	0.2%	0.1%	0.3%	0.6%	0.3%	0.2%	0.4%	0.9%
Nondurable Manufacturing	-0.2%	-0.1%	-0.2%	-0.4%	-0.2%	-0.1%	-0.3%	-0.5%
Chemicals, Plastics, Rubber, and Nonmetallic Mineral Products	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Durable Manufacturing	-0.2%	-0.1%	-0.2%	-0.3%	-0.2%	-0.1%	-0.2%	-0.4%
Trade	-0.2%	-0.1%	-0.2%	-0.4%	-0.2%	-0.2%	-0.3%	-0.5%
Transportation	-0.4%	-0.2%	-0.4%	-0.8%	-0.5%	-0.3%	-0.5%	-1.0%
Communication and Information	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Services	0.1%	0.0%	0.1%	0.2%	0.1%	0.1%	0.1%	0.3%
Real Estate and Owner-Occupied Housing	0.1%	0.1%	0.1%	0.3%	0.2%	0.1%	0.2%	0.4%
All Industries	**-0.03%**	**-0.02%**	**-0.04%**	**-0.05%**	**-0.03%**	**-0.02%**	**-0.04%**	**-0.03%**

Note: Carbon pricing design: lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Consumer Prices. For consumers, carbon pricing in Vermont primarily increases the relative price of transportation and heating fuels. Table 4.6 reflects this reality by displaying the nominal change in prices relative to BAU. The consumer price impacts are greatest for motor vehicle fuels, fuel oil and other fuels (including heating from wood products), and natural gas. Because the policy design under consideration does not preempt RGGI and places no further price on electricity consumption, the nominal price of electricity is largely unaffected by these policies. In 2025, the nominal price of Vermont's consumption goes up between 0.4 and 1.4 percent for the average Vermont household.[59]

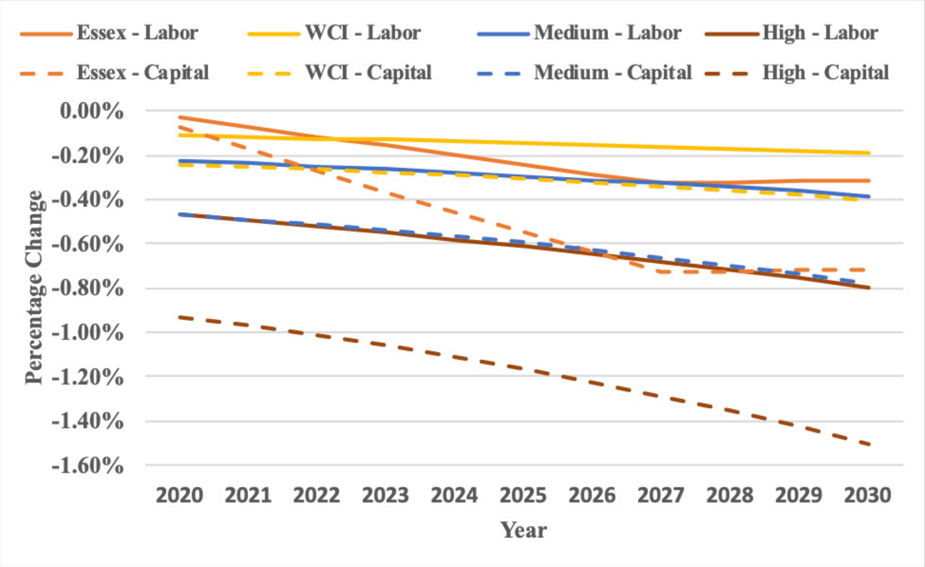
Table 4.6. Percentage Change in Consumer Prices by Carbon Price Path

	2025				2030			
	Carbon Price Path				Carbon Price Path			
Consumer Good	ESSEX	WCI	Medium	High	ESSEX	WCI	Medium	High
Motor Vehicles	0.3%	0.2%	0.3%	0.6%	0.3%	0.2%	0.4%	0.7%
Furnishings and Household Equipment	0.2%	0.1%	0.3%	0.5%	0.3%	0.2%	0.3%	0.6%
Recreation	0.3%	0.2%	0.3%	0.6%	0.3%	0.2%	0.4%	0.7%
Clothing	0.2%	0.2%	0.3%	0.5%	0.3%	0.2%	0.4%	0.7%
Health Care	0.3%	0.2%	0.4%	0.7%	0.4%	0.2%	0.4%	0.8%
Education	0.3%	0.2%	0.4%	0.7%	0.4%	0.2%	0.5%	0.8%
Communication	0.2%	0.1%	0.3%	0.5%	0.3%	0.2%	0.3%	0.6%
Food	0.3%	0.2%	0.3%	0.6%	0.3%	0.2%	0.4%	0.7%
Alcohol	0.2%	0.2%	0.3%	0.5%	0.3%	0.2%	0.4%	0.7%
Motor Vehicle Fuels (and lubricants and fluids)	9.5%	6.2%	12.2%	24.3%	12.7%	7.9%	15.5%	31.1%
Fuel Oil and Other Fuels	6.8%	4.4%	8.6%	17.2%	9.0%	5.6%	11.0%	22.0%
Personal Care	0.3%	0.2%	0.3%	0.6%	0.3%	0.2%	0.4%	0.7%
Tobacco	0.2%	0.2%	0.3%	0.5%	0.3%	0.2%	0.4%	0.7%
Housing	0.4%	0.2%	0.4%	0.7%	0.4%	0.2%	0.4%	0.8%
Water and Waste	0.3%	0.2%	0.4%	0.7%	0.4%	0.2%	0.5%	0.8%
Electricity	0.1%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%
Natural Gas	9.3%	6.0%	12.0%	24.1%	13.5%	8.3%	16.5%	33.2%
Public Ground Transportation	0.9%	0.6%	1.1%	2.2%	1.2%	0.8%	1.4%	2.7%
Air Transportation	1.0%	0.6%	1.2%	2.3%	1.3%	0.8%	1.5%	2.8%
Water Transportation	1.0%	0.6%	1.2%	2.3%	1.3%	0.8%	1.5%	2.8%
Food Services and Accommodations	0.3%	0.2%	0.4%	0.7%	0.4%	0.2%	0.5%	0.8%
Financial Services and Insurance	0.3%	0.2%	0.4%	0.7%	0.4%	0.2%	0.5%	0.8%
Other Services	0.3%	0.2%	0.4%	0.7%	0.4%	0.3%	0.5%	0.9%
Net Foreign Travel	1.0%	0.6%	1.2%	2.3%	1.3%	0.8%	1.5%	2.8%
Consumer Price Index	**0.6%**	**0.4%**	**0.8%**	**1.4%**	**0.8%**	**0.5%**	**0.9%**	**1.8%**

Note: Carbon pricing design: lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Aggregate Household Income. A carbon price affects both capital and labor income through changes in the market-clearing wage and return on capital and through changes in labor and capital supply. It also affects the purchasing power of that income by changing prices of consumer goods. Figure 4.5 displays the impact of the four carbon price paths on real (i.e., adjusted for changes in consumer-good prices) capital and labor income. Under each of the four policies, the reduction in real capital income is greater than the reduction in real labor income; in general, carbon-intensive industries, such as natural gas distribution in Vermont, are also capital-intensive, and thus a carbon price tends to affect capital income more than labor income. As expected, the changes in real capital and labor income are much more dramatic under the high price scenario than the other scenarios. Under the WCI scenario, real labor and capital income fall by less than 0.4 percent relative to BAU.

Figure 4.5. Percentage Change in Real Capital and Labor Income by Carbon Price Path



Interpreting Model Outputs: Household Income

The RFF-DR CGE model uses a representative household, and the changes in household income reported above represent estimated changes to overall labor and capital income for Vermonters. In reality, some Vermont households may experience an increase or no change in income, while others may experience significant declines in income (e.g., through job loss in an affected industry). The results here cannot account for this potentially significant heterogeneity in changes in capital and labor income across households.

Changes in Economic Welfare and Net Benefits. Table 4.7 displays the change in economic welfare and environmental benefits of the carbon pricing policies for Vermont. The change in economic welfare reflects both the change in prices of consumer goods (the use-side impact) and the change in the sources of income (the source-side impact), ignoring the environmental benefits of the policy.[60] Here, we report the total change in economic welfare across all households. In the first year of implementation, total economic welfare falls between $4.3 million and $47.9 million (in 2015$); in 2025, total economic welfare falls between $12.7 million and $61.2 million (in 2015$).[61] On a per capita basis, these economic welfare changes range between $20 and $100.

Measuring the Value of GHG Reductions

To quantify the dollar value of a reduction in GHG emissions, economists use a tool called the social cost of carbon (SCC). The SCC measures the damages, in dollars, of emitting an additional ton of carbon dioxide into the atmosphere. There is significant debate over the value of the SCC, with much of the focus on the choice of the discount rate used to evaluate the cost of future damages today and whether to measure global benefits or only national or subnational benefits.

In this analysis, we use an SCC of $48 in 2020 (in 2015$) and growing to $57.16 in 2030 (in 2015$), reflecting the average SCC, using a 3 percent discount rate, from the Obama administration’s Interagency Working Group’s 2016 update.

Further, we assume that Vermonters care about global well-being and therefore we use estimates for the global social cost of carbon (that is, the total damage to the entire world of emitting an additional ton of carbon). The direct subnational and national impacts will vary tremendously. Even in Vermont, the effect of climate change will vary across businesses and households. Agriculture may experience longer growing seasons, while ski resort operations may be forced to shut down during shorter winters. It is beyond the scope of this report to project impacts of climate change within Vermont.

Table 4.7. Changes in Economic Welfare and Environmental Benefits by Carbon Price Path

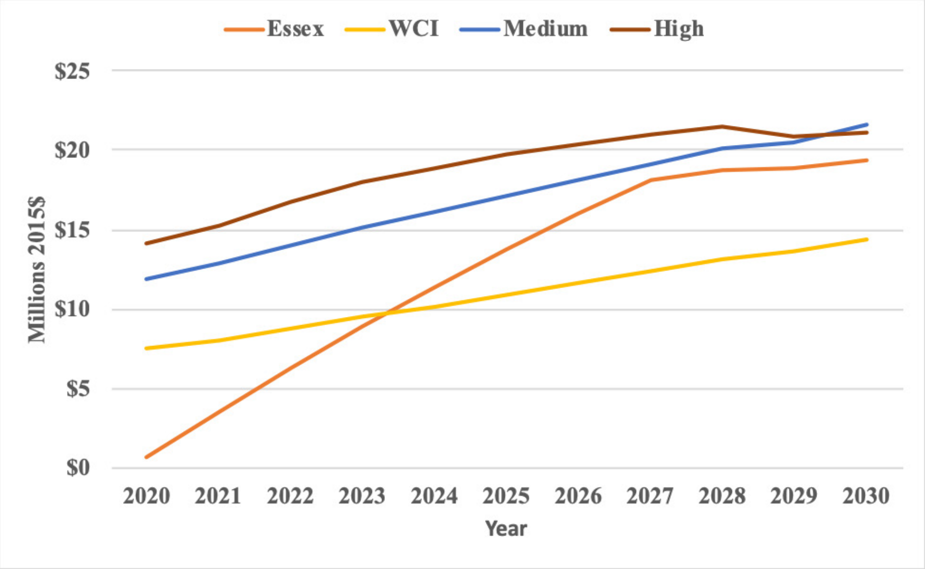
Price Path	Millions (2015$)								
	2020			2025			2030		
	Change in Economic Welfare	Climate Benefits	Health Benefits	Change in Economic Welfare	Climate Benefits	Health Benefits	Change in Economic Welfare	Climate Benefits	Health Benefits
ESSEX	-4.3	3.0	2.0	-21.9	18.5	17.1	-27.4	25.2	21.5
WCI	-10.0	8.9	8.5	-12.7	12.3	11.3	-15.7	16.3	13.8
Medium	-21.2	16.9	16.2	-27.1	23.1	21.2	-34.2	30.1	25.6
High	-47.9	31.5	30.5	-61.2	42.0	38.9	-78.5	53.6	46.1

Note: Carbon pricing design: lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Note: Economic welfare here represents the change in economic welfare across all households; a negative number implies households are worse off, in aggregate, than they would be with no carbon pricing policy.

In most scenarios, the climate benefits of reduced greenhouse gas emissions do not exceed the cost (i.e., the decrease in economic welfare) from the carbon pricing policy (the WCI scenario is an exception in 2030). But carbon pricing also produces health benefits from reduced local air pollution ("Health Benefits" in the table), which are similar in magnitude to the climate benefits. The combined climate and health benefits exceed the cost for every scenario in every year; Figure 4.6 reports net benefits (change in economic welfare plus the environmental benefits) by year for each of the four price paths. The positive net benefits are not dependent on using a high SCC: the policies could still produce positive net benefits even if a much lower SCC estimate were applied. For example, the environmental benefits of the WCI policy would still exceed costs in 2030 as long as the SCC value was $6.66 (in 2015$) or greater.

Figure 4.6. Net Benefits by Carbon Price Path



Measuring the Benefits of Reduced Local Air Pollution

The US EPA's Office of Air Quality Planning and Standards provides estimates of reductions in morbidity and mortality from a reduction of a single ton of $PM_{2.5}$ in the atmosphere ($PM_{2.5}$ can be emitted directly or created through direct SO2 or NO_x emissions) from 17 sectors (EPA 2018a). We use the more conservative Krewski mortality estimates for benefits per ton reduced using a 3 percent discount rate.

Without an air transport model, we assume that all the benefits of reduced $PM_{2.5}$ in Vermont are captured by residents of Vermont.

Note: The health benefits here are only those related to $PM_{2.5}$ pollution (direct and indirect). The benefit estimates do not quantify reductions in other forms of local air pollution created through emissions of local air pollutants.

Distributional Impacts. The change in economic welfare will not be distributed evenly across households. Tables 4.8(a) – 4.8(d) display the change in economic welfare, in dollars per household, for each household income quintile in Vermont (from quintile 1, the lowest-income 20 percent of Vermont households, through quintile 5, the highest-income). These are broken down into the changes caused by price changes for consumer goods and those caused by price changes for sources of income (i.e., changes in wages and returns to capital, and changes in income from other sources). These results estimate only the immediate short-term effects of the policy in its first implementation year of 2020. Further, these results consider only the policy costs and therefore do not include any environmental benefits that stem from reduced emissions of greenhouse gases and changes in conventional air pollutants, the benefits of which may vary by income quintile.

Under each of the four price paths, the change in economic welfare for households in the two lowest income quintiles is positive (i.e., the average household in each of those quintiles is made better off by the policy, even when environmental benefits are ignored) and the change in economic welfare households in the three highest income quintiles is negative.[62] Although lower-income households spend a larger share of their income on energy than higher-income households, they spend less in absolute terms. Because these policies all feature lump-sum rebates and the lump-sum rebates more than offset the burden of higher consumer-good prices for low-income households, the change in economic welfare for these households is positive (i.e. they are better off as a result of the policy). For higher-income households, the lump-sum rebates aren't sufficient to offset the burden of higher consumer-good prices. Higher carbon prices amplify this distributional outcome, leading to greater positive impacts for lower-income households and greater negative impacts for higher-income households. Across all households and policy scenarios, the magnitude of economic welfare impacts is minor: the change in economic welfare is less than 0.5 percent of average household income for all income quintiles and policy scenarios.

Table 4.8(a). Changes in Economic Welfare by Households (Income) under ESSEX Price Path, 2020

Economic welfare change by quintile (2015$ per household)	1	2	3	4	5
Energy Goods	-25.56	-40.07	-59.21	-55.42	-82.70
Electricity	0.20	0.26	0.32	0.32	0.43
Fuel Oil and Other Fuels	-13.13	-18.56	-28.08	-21.07	-38.24
Motor Vehicle Fuels (and lubricants and fluids)	-11.51	-20.27	-29.70	-32.82	-42.38
Natural Gas	-1.12	-1.51	-1.75	-1.85	-2.51
Other Goods	-39.48	-55.74	-73.76	-82.74	-146.15
Sources of Income	98.78	107.89	120.51	138.86	119.34
Capital	0.54	1.01	2.52	4.73	23.67
Labor	9.76	22.78	45.28	78.16	153.70
Other Sources	88.47	84.09	72.71	55.97	-58.03
Total	**33.74**	**12.08**	**-12.46**	**0.70**	**-109.51**

Note: Carbon pricing design: ESSEX price path, lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Table 4.8(b). Changes in Economic Welfare by Households (Income) under WCI Price Path, 2020

Economic Welfare Change by Quintile (2015$ per household)	**1**	**2**	**3**	**4**	**5**
Energy Goods	-75.83	-119.03	-176.19	-164.75	-246.11
Electricity	1.12	1.48	1.82	1.82	2.43
Fuel Oil and Other Fuels	-39.42	-55.69	-84.29	-63.24	-114.77
Motor Vehicle Fuels (and lubricants and fluids)	-34.43	-60.64	-88.85	-98.19	-126.80
Natural Gas	-3.10	-4.18	-4.86	-5.14	-6.97
Other Goods	-86.90	-122.65	-162.40	-182.25	-322.18
Sources of Income	282.26	296.51	313.71	338.63	249.53
Capital	0.85	1.59	3.95	7.42	37.16
Labor	17.42	40.65	80.81	139.48	274.29
Other Sources	263.99	254.26	228.95	191.72	-61.93
Total	**119.54**	**54.82**	**-24.88**	**-8.38**	**-318.76**

Note: Carbon pricing design: WCI price path, lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Table 4.8(c). Changes in Economic Welfare by Households (Income) under Medium Price Path, 2020

Economic Welfare Change by Quintile (2015$ per household)	**1**	**2**	**3**	**4**	**5**
Energy Goods	-147.21	-230.95	-341.73	-319.45	-477.36
Electricity	2.20	2.90	3.58	3.58	4.79
Fuel Oil and Other Fuels	-76.57	-108.19	-163.74	-122.85	-222.96
Motor Vehicle Fuels (and lubricants and fluids)	-66.51	-117.13	-171.63	-189.68	-244.93
Natural Gas	-6.33	-8.54	-9.94	-10.51	-14.25
Other Goods	-165.39	-233.47	-309.15	-346.96	-613.41
Sources of Income	538.15	564.49	595.83	641.19	465.24
Capital	1.57	2.94	7.29	13.70	68.58
Labor	32.63	76.14	151.37	261.26	513.76
Other Sources	503.94	485.42	437.17	366.23	-117.11
Total	**225.55**	**100.08**	**-55.05**	**-25.22**	**-625.53**

Note: Carbon pricing design: medium price path, lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Table 4.8(d). Changes in Economic Welfare by Households (Income) under High Price Path, 2020

Economic Welfare Change by Quintile (2015$ per household)	1	2	3	4	5
Energy Goods	-286.21	-448.54	-663.26	-619.69	-926.47
Electricity	4.38	5.77	7.12	7.12	9.51
Fuel Oil and Other Fuels	-148.96	-210.46	-318.53	-238.99	-433.74
Motor Vehicle Fuels (and lubricants and fluids)	-128.13	-225.65	-330.67	-365.43	-471.88
Natural Gas	-13.49	-18.19	-21.18	-22.38	-30.36
Other Goods	-309.77	-437.36	-579.20	-650.17	-1149.64
Sources of Income	1010.15	1056.82	1110.60	1188.34	836.59
Capital	2.78	5.20	12.91	24.25	121.40
Labor	59.27	138.29	274.93	474.55	933.18
Other Sources	948.10	913.33	822.75	689.55	-217.99
Total	**414.17**	**170.92**	**-131.87**	**-81.52**	**-1239.52**

Note: Carbon pricing design: high price path, lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Tables 4.8(e) – 4.8(h) display the changes in economic welfare, in dollars per household, for each of the fourteen counties in Vermont. All counties have negative economic welfare impacts, but the magnitudes of these impacts are small (less than 0.4 percent of household income even under the highest price path). This is because although households in Vermont counties have a range of household incomes, the mean households in each county fall into the third- and fourth-income quintiles, which tend to have slightly negative economic welfare impacts. Rural counties with higher fuel oil and transportation expenditures have greater expenditure impacts from the policy, but these are somewhat offset by income benefits that are most beneficial for lower income counties.

Under each of the four price paths, Chittenden County has the least negative economic welfare impacts because the county has relatively low expenditures on home heating and transportation. Grand Isle, with the highest home heating and transportation expenditures, has the greatest negative economic welfare impacts.

Note that these average county-level impacts do not capture the substantial within-county heterogeneity: some households within each county will do substantially better than the mean and others substantially worse. Due to data limitations, we cannot rigorously model that heterogeneity. But based on the results across income groups at the state level, one would expect a similar pattern within each county: lower-income households would tend to do better than the county average, and higher-income households worse, due to the effect of the lump-sum rebates (which are a larger percentage of income for lower-income households).

Interpreting Model Outputs: Economic Welfare Changes by Households

The RFF-DR CGE model estimates overall changes in expenditures and income for Vermonters. The RFF incidence model uses the estimated changes in expenditures and income to calculate welfare changes by household group (income quintile or county) based on the shares of total baseline expenditures and income that accrues to each household group. In reality, the changes in expenditures and income vary across household groups. Additionally, expenditures and income vary for households within each household group. The reported results reflect average impacts within each household group and they mask potentially large heterogeneity.

In the RFF Incidence model, expenditures and income are expressed in nominal terms rather than real. Although nominal income increases under many policy scenarios, the difference between income and expenditures may increase or decrease.

Table 4.8(e). Changes in Economic Welfare by County (Average Household) under ESSEX Price Path, 2020

Economic Welfare change by county (2015$ per household)	Addison	Bennington	Caledonia	Chittenden	Essex	Franklin	Grand Isle	Lamoille	Orange	Orleans	Rutland	Washington	Windham	Windsor
Energy Goods	**-57.48**	**-57.60**	**-58.90**	**-41.49**	**-59.77**	**-57.04**	**-63.73**	**-53.33**	**-55.44**	**-55.76**	**-57.26**	**-54.86**	**-53.16**	**-56.29**
Electricity	0.35	0.34	0.30	0.29	0.26	0.34	0.28	0.30	0.29	0.25	0.33	0.30	0.31	0.33
Fuel Oil and Other Fuels	-28.87	-30.81	-29.62	-12.03	-28.88	-24.85	-29.98	-25.15	-25.77	-27.73	-30.27	-27.72	-25.60	-27.02
Motor Vehicle Fuels (and lubricants and fluids)	-28.79	-26.91	-29.47	-23.92	-31.09	-29.93	-33.76	-28.33	-29.79	-28.22	-27.19	-27.23	-27.75	-29.38
Natural Gas	-0.17	-0.21	-0.11	-5.83	-0.07	-2.60	-0.26	-0.15	-0.17	-0.06	-0.13	-0.21	-0.12	-0.23
Other Goods	**-81.40**	**-76.59**	**-72.88**	**-86.51**	**-65.91**	**-80.80**	**-83.02**	**-77.62**	**-77.94**	**-70.51**	**-74.52**	**-80.53**	**-75.02**	**-79.36**
Sources of Income	**117.89**	**117.31**	**115.12**	**118.46**	**112.35**	**117.30**	**120.47**	**116.52**	**116.21**	**113.99**	**115.63**	**117.20**	**116.18**	**117.93**
Capital	6.74	5.85	4.73	8.40	3.41	6.56	7.65	5.94	5.71	4.31	5.18	6.60	5.32	6.60
Labor	64.14	58.85	50.51	73.45	40.45	62.53	71.87	58.43	56.87	47.03	53.44	62.64	54.81	63.44
Other Sources	47.01	52.61	59.88	36.61	68.48	48.20	40.95	52.15	53.63	62.65	57.01	47.96	56.05	47.89
Total	**-21.00**	**-16.88**	**-16.66**	**-9.54**	**-13.34**	**-20.54**	**-26.28**	**-14.44**	**-17.17**	**-12.28**	**-16.16**	**-18.19**	**-12.00**	**-17.73**

Note: Carbon pricing design: ESSEX price path, lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Table 4.8(f). Changes in Economic Welfare by County (Average Household) under WCI Price Path, 2020

Economic Welfare Change by County (2015$ per household)	Addison	Bennington	Caledonia	Chittenden	Essex	Franklin	Grand Isle	Lamoille	Orange	Orleans	Rutland	Washington	Windham	Windsor
Energy Goods	**-171.31**	**-171.68**	**-175.71**	**-122.19**	**-178.42**	**-169.42**	**-190.16**	**-159.00**	**-165.32**	**-166.42**	**-170.73**	**-163.56**	**-158.45**	**-167.77**
Electricity	1.95	1.90	1.67	1.64	1.44	1.93	1.55	1.66	1.64	1.42	1.83	1.69	1.75	1.84
Fuel Oil and Other Fuels	-86.65	-92.47	-88.91	-36.11	-86.67	-74.57	-89.98	-75.48	-77.35	-83.23	-90.85	-83.21	-76.85	-81.09
Motor Vehicle Fuels (and lubricants and fluids)	-86.15	-80.52	-88.16	-71.57	-93.00	-89.56	-101.01	-84.76	-89.13	-84.43	-81.33	-81.45	-83.03	-87.90
Natural Gas	-0.47	-0.59	-0.30	-16.16	-0.19	-7.22	-0.72	-0.42	-0.47	-0.17	-0.37	-0.58	-0.33	-0.62
Other Goods	**-179.30**	**-168.69**	**-160.50**	**-190.59**	**-145.14**	**-177.99**	**-182.87**	**-170.98**	**-171.67**	**-155.28**	**-164.13**	**-177.39**	**-165.23**	**-174.80**
Sources of Income	**296.80**	**298.42**	**297.96**	**292.90**	**297.07**	**296.31**	**298.55**	**296.80**	**296.95**	**297.24**	**297.50**	**296.03**	**298.03**	**297.29**
Capital	10.58	9.18	7.43	13.19	5.36	10.30	12.01	9.33	8.97	6.77	8.14	10.37	8.36	10.35
Labor	114.46	105.03	90.14	131.08	72.19	111.60	128.26	104.27	101.50	83.92	95.36	111.79	97.81	113.21
Other Sources	171.76	184.21	200.39	148.63	219.52	174.41	158.28	183.19	186.48	206.55	194.00	173.87	191.87	173.72
Total	**-53.81**	**-41.95**	**-38.25**	**-19.88**	**-26.48**	**-51.09**	**-74.48**	**-33.18**	**-40.04**	**-24.45**	**-37.35**	**-44.92**	**-25.65**	**-45.28**

Note: Carbon pricing design: WCI price path, lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Table 4.8(g). Changes in Economic Welfare by County (Average Household) under Medium Price Path, 2020

Economic Welfare Change by County (2015$ per household)	Addison	Bennington	Caledonia	Chittenden	Essex	Franklin	Grand Isle	Lamoille	Orange	Orleans	Rutland	Washington	Windham	Windsor
Energy Goods	**-331.84**	**-332.63**	**-340.35**	**-238.19**	**-345.55**	**-328.82**	**-368.34**	**-307.94**	**-320.18**	**-322.34**	**-330.75**	**-316.85**	**-306.89**	**-324.97**
Electricity	3.84	3.75	3.28	3.23	2.84	3.80	3.06	3.28	3.22	2.79	3.59	3.32	3.44	3.62
Fuel Oil and Other Fuels	-168.33	-179.64	-172.72	-70.14	-168.36	-144.86	-174.80	-146.62	-150.26	-161.68	-176.48	-161.65	-149.28	-157.52
Motor Vehicle Fuels (and lubricants and fluids)	-166.40	-155.54	-170.29	-138.24	-179.65	-173.00	-195.11	-163.73	-172.17	-163.09	-157.11	-157.34	-160.38	-169.79
Natural Gas	-0.95	-1.20	-0.61	-33.04	-0.39	-14.76	-1.48	-0.86	-0.97	-0.35	-0.76	-1.18	-0.67	-1.28
Other Goods	**-341.34**	**-321.14**	**-305.54**	**-362.83**	**-276.29**	**-338.83**	**-348.13**	**-325.49**	**-326.80**	**-295.59**	**-312.44**	**-337.69**	**-314.55**	**-332.77**
Sources of Income	**562.11**	**565.59**	**565.30**	**553.98**	**564.31**	**561.29**	**564.91**	**562.51**	**562.91**	**564.18**	**564.21**	**560.74**	**565.14**	**563.10**
Capital	19.52	16.95	13.71	24.35	9.89	19.01	22.16	17.22	16.55	12.50	15.01	19.13	15.42	19.11
Labor	214.38	196.73	168.83	245.51	135.21	209.03	240.23	195.31	190.11	157.19	178.62	209.39	183.20	212.06
Other Sources	328.21	351.92	382.76	284.13	419.21	333.26	302.52	349.98	356.25	394.49	370.58	332.22	366.52	331.94
Total	**-111.07**	**-88.17**	**-80.59**	**-47.04**	**-57.53**	**-106.36**	**-151.56**	**-70.91**	**-84.06**	**-53.76**	**-78.98**	**-93.80**	**-56.30**	**-94.64**

Note: Carbon pricing design: medium price path, lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Table 4.8(h). Changes in Economic Welfare by County (Average Household) under High Price Path, 2020

Economic Welfare Change by County (2015$ per household)	Addison	Bennington	Caledonia	Chittenden	Essex	Franklin	Grand Isle	Lamoille	Orange	Orleans	Rutland	Washington	Windham	Windsor
Energy Goods	**-642.45**	**-644.24**	**-658.88**	**-466.74**	**-668.81**	**-639.00**	**-713.04**	**-596.00**	**-619.68**	**-623.96**	**-640.48**	**-613.51**	**-593.99**	**-629.08**
Electricity	7.64	7.44	6.52	6.42	5.64	7.54	6.07	6.51	6.40	5.54	7.14	6.60	6.83	7.20
Fuel Oil and Other Fuels	-327.47	-349.46	-336.01	-136.45	-327.52	-281.81	-340.06	-285.23	-292.30	-314.53	-343.32	-314.46	-290.40	-306.43
Motor Vehicle Fuels (and lubricants and fluids)	-320.59	-299.66	-328.09	-266.34	-346.12	-333.29	-375.90	-315.45	-331.71	-314.22	-302.68	-303.13	-308.99	-327.12
Natural Gas	-2.03	-2.56	-1.30	-70.37	-0.82	-31.44	-3.16	-1.84	-2.06	-0.75	-1.61	-2.51	-1.43	-2.72
Other Goods	**-639.60**	**-601.72**	**-572.49**	**-679.89**	**-517.64**	**-634.90**	**-652.33**	**-609.88**	**-612.34**	**-553.84**	**-585.43**	**-632.76**	**-589.37**	**-623.53**
Sources of Income	**1042.10**	**1049.99**	**1051.49**	**1024.41**	**1052.11**	**1040.95**	**1045.49**	**1044.26**	**1045.41**	**1050.23**	**1048.72**	**1039.87**	**1050.13**	**1044.14**
Capital	34.55	30.00	24.26	43.09	17.51	33.64	39.22	30.48	29.30	22.12	26.57	33.86	27.29	33.82
Labor	389.40	357.32	306.66	445.94	245.60	379.67	436.35	354.76	345.31	285.52	324.44	380.32	332.76	385.17
Other Sources	618.15	662.67	720.57	535.38	789.01	627.63	569.92	659.03	670.80	742.59	697.72	625.69	690.08	625.15
Total	**-239.95**	**-195.97**	**-179.88**	**-122.22**	**-134.34**	**-232.95**	**-319.88**	**-161.62**	**-186.61**	**-127.57**	**-177.18**	**-206.41**	**-133.23**	**-208.47**

Note: Carbon pricing design: high price path, lump-sum rebates, economy-wide (electricity exempt), Vermont only.

4.4. Revenue Use

Carbon pricing policies (except cap-and-trade programs with free allocation of allowances) raise revenues, a distinct advantage over regulatory policies. Policymakers can use these revenues in a number of ways, such as to finance general state expenditures; cut sales, income, property, or other taxes; or finance "green" investments. As discussed in Goulder and Hafstead (2017), Barron et al. (2018), and others, the use of revenues plays a key role in determining the overall costs and the distribution of those costs across households.

Net Revenues vs. Gross Revenues

Economists refer to the carbon revenues collected by the state as *gross revenues*. Gross revenues will be equal to emissions covered by the policy times the carbon price. Carbon pricing, however, will tend to reduce the size of other state revenues (e.g., reductions in income will reduce income tax revenue, and reductions in gasoline use will reduce gasoline tax revenues) and increase the level of state expenditures needed to provide a given level of services (because carbon pricing increases the price of some goods purchased by the state). *Net revenue* refers to the value of gross revenues net of changes in other state revenues and any changes in the level of state expenditures needed to maintain existing levels of state services (for example, higher fuel prices would raise the cost of heating public buildings and running public buses, but fewer vehicle miles travelled would reduce costs of annual highway maintenance). For this analysis, we define revenue-neutral policies as those that return 100 percent of net revenue (not gross revenue) to the private sector.

In the quantitative analysis in this section, we focus on three revenue-neutral revenue options.[63]

- *Lump-Sum Rebates*. Net revenue is returned equally through equal per household payments to all Vermont households.
- *Tax Cuts on Wage Income*. Net revenue is used to finance reductions in state taxes on wage income.
- *Electricity Rebates*. Net revenue is used to finance reductions in electricity rates for residential, commercial, and industrial customers.

For tractability of our analysis, we consider only policies that allocate 100 percent of the net revenue to a single use. Of course, policymakers are not restricted to use all the revenue in one place, and they may in fact choose a combination of alternative uses. And again, for each revenue use, we hold fixed the carbon price path, the sectoral coverage, and the regional scope of the policy. **In this section, all policies use the WCI price path, cover transportation and heating fuels only, and cover Vermont emissions only**.

Using Carbon Price Revenue to Finance Green Investment

The RFF-DR CGE model cannot evaluate the economic impacts of using carbon revenues to finance green investments. We lack sufficient data on the relationship between the green investment, emissions, and the flow of investment spending through the economy to firms and households in both Vermont and the rest of the country. As discussed in Appendix B, the backbone of the RFF-DR CGE model is a social accounting matrix that tracks market and nonmarket financial flows across firms, households, and governments within and across regions in the United States. Without corresponding estimates of the flows from different forms of green investment, the model cannot accurately assess the economic impacts of green investments. Further, without concrete estimates on how green investments affect energy expenditures and how energy expenditures vary with the size of green investments for each type of agent in the model (firms, households, and governments), the model cannot produce reliable estimates of the emissions reductions that would occur from using carbon revenue to finance green investment. As a result, we do not apply the RFF-DR CGE model to evaluate green investments.

Policymakers, however, do have the option to use revenues to finance green investments, and it is a reasonable question to ask how the effects of green spending would change the economic and environmental impacts of a carbon pricing policy. On the economic side of the ledger, most evidence suggests that green investments would increase costs relative to the lump-sum rebate option and exacerbate distributional issues. For example, the California Air Resources Board forecast that a policy that “relies on prescriptive measures to achieve the SB32 target and does not include any carbon pricing mechanism” would result in costs that were 16.4 times greater than the proposed plan that included a cap-and-trade program (CARB 2017). And Borenstein and Davis (2016) find that US tax credits for clean energy investments have gone disproportionately to higher-income households, and therefore such tax credits have substantially more regressive distributional effects than carbon pricing would. But a full evaluation of green investment programs (and of nonpricing policies more generally) will require further research.

Environmentally, the change in emissions would depend on the amount of revenue spent on each investment option and the estimated cost per ton reduced for each technology. But there is increasing evidence that nonpricing programs deliver much smaller benefits than projected; for example, Fowlie et al. (2018) show using a large-scale randomized experiment that a weatherization program in Michigan produced energy savings that were only one-third as large as initially projected (and the program delivered a negative return on investment). In Section 4.8, we add *median* estimates for emissions reductions across a range of nonpricing options to the carbon pricing reductions to estimate the potential emissions reductions from a comprehensive pricing and nonpricing approach.

4.4.1. Environmental Impacts

GHG Emissions Levels. Figure 4.7 displays historical and projected greenhouse gas emissions for the state of Vermont from 2015 to 2030 under business as usual and the three revenue use options. The choice of revenue use has little to no impact on the level of emissions reductions under the policy.[64] The emissions reductions under lump-sum rebates and tax cuts on wage income ("labor tax cuts") are virtually identical. Under the electricity rebate policy, consumption-based electricity emissions slightly increase relative to the other revenue uses, as the policy increases generation and emissions from generation in ISO New England. Table 4.9 displays the emissions projections across sectors in 2025 and 2030.

Figure 4.7. Vermont GHG Emissions by Revenue Use (Carbon Pricing Only)

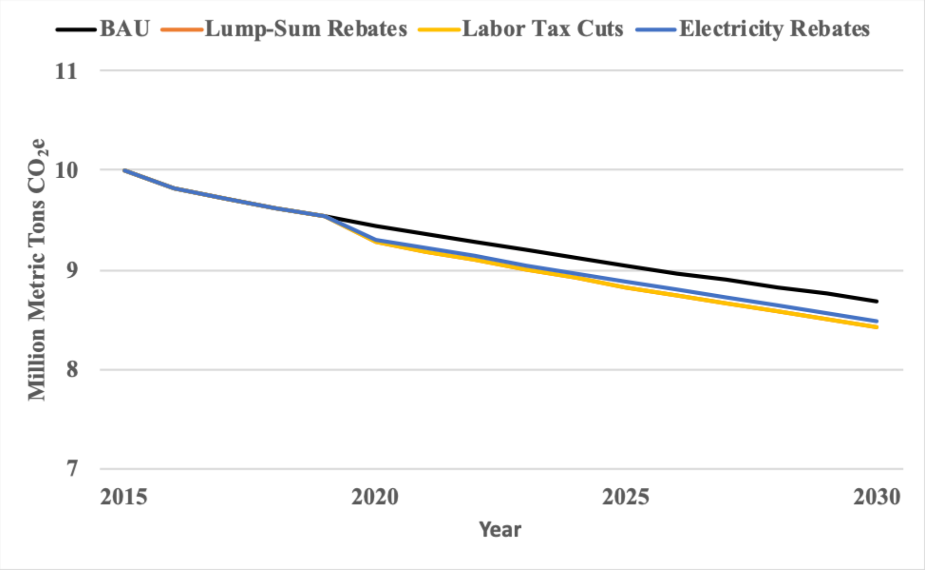


Table 4.9. Vermont GHG Emissions by Sector by Revenue Use (Carbon Pricing Only)

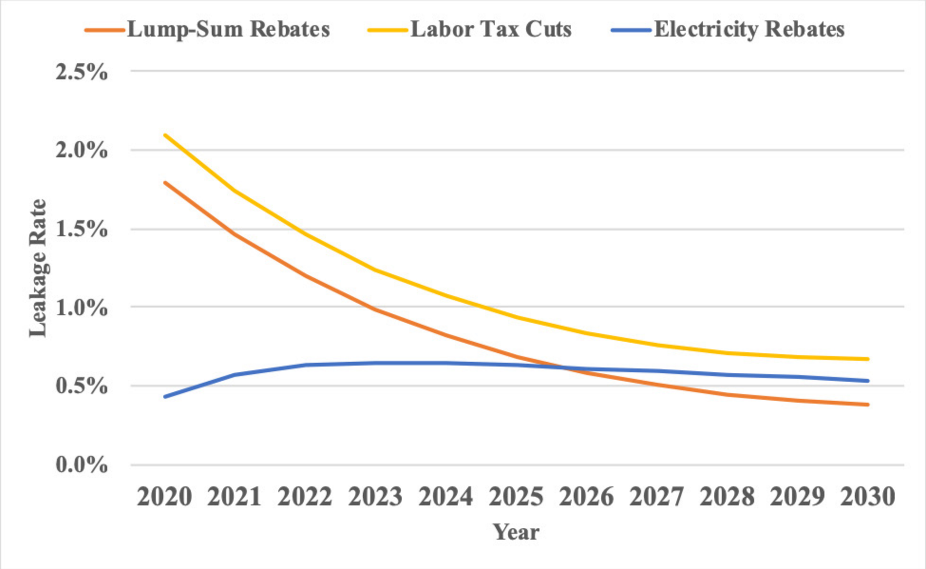
Million Metric Tons CO_2 Equivalent ($MMTCO_2e$)									
	2015	2025				2030			
	Historical		Revenue Use				Revenue Use		
Sector		BAU	Lump-Sum Rebates	Labor Tax Cuts	Electricity Subsidies	BAU	Lump-Sum Rebates	Labor Tax Cuts	Electricity Subsidies
Electricity (consumption based)	1.0	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6
Residential/Commercial/ Industrial Fuel Use	2.8	2.5	2.4	2.4	2.4	2.4	2.3	2.3	2.4
Transportation	4.3	4.0	3.8	3.8	3.8	3.8	3.6	3.6	3.6
Fossil Fuel Industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial Processes	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Waste Management	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Agriculture	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Total	**10.0**	**9.1**	**8.8**	**8.8**	**8.9**	**8.7**	**8.4**	**8.4**	**8.5**
Total Relative to 1990	**16%**	**6%**	**3%**	**3%**	**3%**	**1%**	**-2%**	**-2%**	**-1%**
Total Relative to 2005	**-2%**	**-11%**	**-14%**	**-14%**	**-13%**	**-15%**	**-18%**	**-18%**	**-17%**

Note: Carbon pricing design: WCI price path, transportation and heating fuels, Vermont only.

Leakage rates do vary by revenue use. Figure 4.8 displays leakage rates (for CO_2) by revenue use. Relative to lump-sum rebates, tax cuts on wage income slightly increase emissions in neighboring states. Higher relative income in Vermont from the labor tax cuts increases consumption and imports of all types of goods, increasing emissions associated with the production of imported goods in neighboring states. Electricity rebates have a smaller leakage rate in the short-run relative to other revenue uses; consumers and firms shift consumption toward electricity and away from other goods. The net result is a small relative decline in imports and a smaller increase in neighboring emissions.

The electricity subsidy policy, unlike other policies considered, could increase methane emissions in neighboring states if the increased electricity demand from Vermont was met, in full or in part, by increased natural gas generation in neighboring states. If, on the other hand, increased electricity demand was met by renewable generation in-state or by Hydro Québec, then methane emissions would not be expected to increase as a result of the electricity subsidies. Further research using detailed electricity models would be required to assess how this increased electricity demand would be met.

Figure 4.8. Leakage Rates to Northeast States by Revenue Use



Local Criteria Air Pollutants. Table 4.10 reports the changes in local criteria air pollutant emissions by pollutant and revenue use. A carbon pricing policy with reductions in taxes on wage income (i.e., labor tax cuts) increases economic activity relative to a carbon pricing policy with lump-sum rebates. As a result, the reductions in local criteria air pollutant emissions are slightly smaller with reductions in labor tax rates than lump-sum rebates, though this difference is very small. Electricity subsidies, on the other hand, promote the production and transmission of electricity and as a result there are much smaller reductions in carbon monoxide and nitrogen oxide emissions than the other forms of revenue use.

Table 4.10. Percentage Change in Criteria Air Pollutant Emissions by Revenue Use

BAU and Historical:1000 tons; Carbon Pricing: Percentage Change from BAU									
	2015	2025				2030			
	Historical		Revenue Use				Revenue Use		
Criteria Air Pollutant		BAU	Lump-Sum Rebates	Labor Tax Cuts	Electricity Subsidies	BAU	Lump-Sum Rebates	Labor Tax Cuts	Electricity Subsidies
Carbon Monoxide (CO)	135.8	122.9	-1.6%	-1.6%	-0.9%	118.3	-2.0%	-2.0%	-1.1%
Nitrogen Oxide (NOx)	15.5	14.1	-3.0%	-3.0%	-2.3%	13.5	-3.8%	-3.7%	-2.9%
Particulate Matter 10 (PM10)	10.3	9.1	-0.3%	-0.2%	-0.3%	8.9	-0.4%	-0.2%	-0.4%
Particulate Matter 2.5 (PM2.5)	9.0	8.0	-0.1%	0.0%	-0.1%	7.8	-0.2%	0.0%	-0.2%
Sulfur Dioxide (SO2)	1.4	1.3	-2.2%	-2.1%	-2.1%	1.2	-2.7%	-2.6%	-2.7%
Volatile Organic Compounds (VOC)	19.6	17.7	-1.0%	-1.0%	0.0%	17.0	-1.3%	-1.2%	0.1%
Ammonia (NH3)	0.7	0.6	-1.9%	-1.8%	-2.0%	0.6	-2.4%	-2.3%	-2.5%

4.4.2. Economic Impacts

Gross Carbon Revenue. Because the three revenue use options all produce approximately the same level of emissions, annual gross carbon revenues collected by the state will also be approximately equal. Table 4.11 displays the level of carbon revenues in 2020, 2025, and 2030 in 2015$.

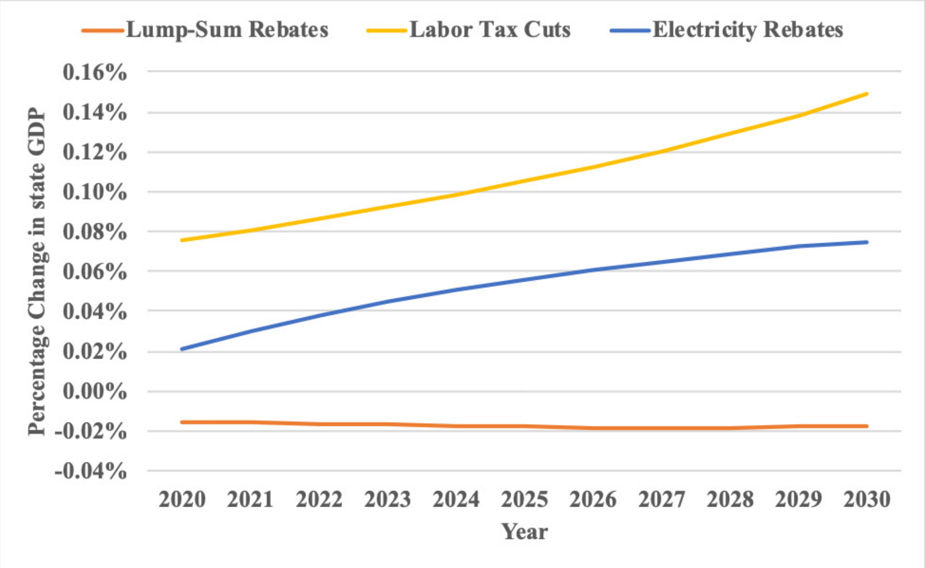
Table 4.11. Annual Gross Carbon Revenue by Revenue Use

	Millions (2015$)		
Revenue Use	**2020**	**2025**	**2030**
Lump-Sum Rebates	94.1	114.3	138.9
Labor Tax Cuts	94.2	114.3	138.9
Electricity Rebates	94.1	114.4	139.1

Note: Carbon pricing design: WCI price path, transportation and heating fuels, Vermont only.

Macroeconomic Impacts. As shown in Figure 4.9, the macroeconomic impacts of carbon pricing policies significantly depend on the use of carbon revenues. Under lump-sum rebates, Vermont's state GDP declines. Under the two alternative revenue use options considered, state GDP increases. Cuts in taxes on wage income (i.e., labor tax cuts) increase households' incentive to work and save, thus boosting state GDP. Electricity rebates also have a positive (but smaller) effect, because lowering electricity prices to households slightly reduces the increased cost of living (relative to the rebate policy), thus slightly increasing the real value of wages, again increasing the incentive to work, and lowering electricity prices for business lowers production costs slightly (relative to the rebate policy), thus encouraging more production – effects that are small, but nonetheless significant. Lump-sum rebates don't affect incentives, and thus don't provide the same kind of boost as the other two revenue-use options. Assuming an average 1 percent growth rate in state GDP between 2015 and 2025, the increase in state GDP would be $35.6million in 2025 under labor tax cuts and $19.0 million in 2025 under electricity rebates (in 2015$), compared with a decline of $6.0 million (in 2015$) under lump-sum rebates.

Figure 4.9. Percentage Change in Vermont GDP by Revenue Use



The relative impacts of the carbon price by sector are relatively consistent across revenue use options. Table 4.12 reports the percentage change in output by industry across the three revenue use options. In most cases, reductions in taxes on wage earnings or electricity rates lead to slightly smaller output declines in negatively affected industries and slightly higher output in positively affected industries. The exception is the impact of electricity rate reductions on Vermont's electric power sector. Both electric generation and electric transmission/distribution would experience large increases in output due to increases in electricity demand under the electricity rebate policy.

Table 4.12. Percentage Change in Industry Output by Revenue Use

Industry	2025 Revenue Use			2030 Revenue Use		
	Lump-Sum Rebates	Labor Tax Cuts	Electricity Subsidies	Lump-Sum Rebates	Labor Tax Cuts	Electricity Subsidies
Electricity Generation	-0.1%	-0.1%	1.2%	-0.1%	-0.1%	1.6%
Electric Transmission and Distribution	-0.2%	-0.2%	6.5%	-0.3%	-0.3%	8.6%
Natural Gas Distribution	-3.7%	-3.6%	-3.4%	-5.0%	-4.9%	-4.6%
Other Mining and Mining Services	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%
Farms, Forestry, Fishing	-0.1%	0.0%	-0.1%	-0.1%	0.0%	-0.1%
Construction	-0.6%	-0.5%	-0.6%	-0.7%	-0.6%	-0.7%
Nondurable Manufacturing	-0.1%	0.0%	-0.1%	-0.1%	0.0%	-0.2%
Chemicals, Plastics, Rubber, and Nonmetallic Mineral Products	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%
Durable Manufacturing	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%
Trade	-0.1%	0.0%	0.0%	-0.1%	0.0%	0.1%
Transportation	-0.1%	0.0%	0.0%	-0.2%	0.0%	0.0%
Communication and Information	0.0%	0.1%	0.0%	0.1%	0.2%	0.0%
Services	0.0%	0.1%	0.0%	0.1%	0.2%	0.0%
Real Estate and Owner-Occupied Housing	0.1%	0.1%	0.1%	0.1%	0.2%	0.1%
All Industries	**-0.03%**	**0.05%**	**0.10%**	**-0.04%**	**0.08%**	**0.13%**

Note: Carbon pricing design: WCI price path, transportation and heating fuels, Vermont only.

Labor Demand Impacts. As was the case for alternative carbon price paths, the impacts on labor demand across sectors largely mirror the impacts on output across sectors. Table 4.13 reports the percentage change in labor demand by sector across the three revenue use options. Under the labor tax cut scenario (i.e., reductions in taxes on wage earnings), the increase in labor demand in sectors that are both non-carbon-intensive and labor-intensive is greater than the increase in labor demand in those same sectors under lump-sum rebates. Further, some industries that have negative labor demand impacts under lump-sum rebates, such as trade and transportation, experience labor demand increases under the labor tax cut scenario. As a result, total labor demand is projected to increase in Vermont under the labor tax cut scenario.

Under the electricity subsidies scenario, labor demand increases in both the electricity generation and electric transmission and distribution sectors; the electricity subsidy significantly increases demand for electricity across all sectors. Other industries also increase their labor demand in the electricity subsidies scenario, but the changes are smaller relative to the increases in labor demand under the labor tax cuts scenario.

Table 4.13. Percentage Change in Labor Demand by Revenue Use

Industry	2025 Revenue Use			2030 Revenue Use		
	Lump-Sum Rebates	Labor Tax Cuts	Electricity Subsidies	Lump-Sum Rebates	Labor Tax Cuts	Electricity Subsidies
Electricity Generation	-0.1%	0.1%	1.6%	-0.2%	0.1%	1.9%
Electric Transmission and Distribution	-0.4%	-0.1%	7.0%	-0.5%	-0.1%	9.0%
Natural Gas Distribution	-4.2%	-4.0%	-3.9%	-5.4%	-5.1%	-4.9%
Other Mining and Mining Services	-0.1%	0.1%	-0.1%	-0.1%	0.2%	-0.1%
Farms, Forestry, Fishing	-0.2%	0.1%	-0.1%	-0.2%	0.1%	-0.1%
Construction	0.1%	0.4%	0.2%	0.2%	0.5%	0.2%
Nondurable Manufacturing	-0.1%	0.1%	-0.1%	-0.2%	0.1%	-0.1%
Chemicals, Plastics, Rubber, and Nonmetallic Mineral Products	0.0%	0.2%	0.1%	0.0%	0.2%	0.1%
Durable Manufacturing	-0.1%	0.1%	0.0%	-0.1%	0.2%	-0.1%
Trade	-0.1%	0.1%	0.0%	-0.2%	0.1%	-0.1%
Transportation	-0.2%	0.1%	0.0%	-0.3%	0.1%	0.0%
Communication and Information	0.0%	0.3%	0.0%	0.0%	0.3%	0.0%
Services	0.1%	0.3%	0.0%	0.1%	0.4%	0.0%
Real Estate and Owner-Occupied Housing	0.1%	0.3%	-0.1%	0.1%	0.4%	-0.1%
All Industries	**-0.02%**	**0.21%**	**0.05%**	**-0.02%**	**0.27%**	**0.04%**

Note: Carbon pricing design: WCI price path, transportation and heating fuels, Vermont only.

Consumer Prices. The relative changes in consumer prices are similar across the three revenue use options, as displayed in Table 4.14. Because the policy only covers transportation and heating fuels in these scenarios, the price impacts are concentrated in motor vehicle fuels, fuel oils and other fuels, and natural gas. Households also experience more modest increases in the price of public ground, air, and water transportation. Under electricity rebates, households also experience a sharp decline in the price of electricity relative to BAU. In 2025, the retail price of electricity is projected to fall by 9.3 percent for residential consumers under the electricity rebate scenario. As a result, the overall change in consumer prices, holding fixed the average basket of consumption, is smallest under the electricity rebate policy.

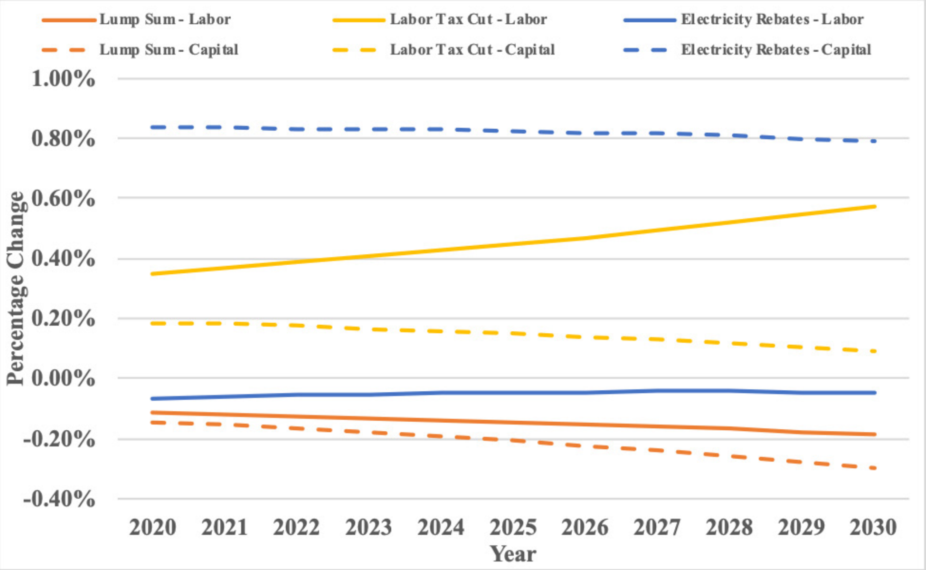
Table 4.14. Percentage Change in Consumer Prices by Revenue Use

Consumer Good	2025 Revenue Use			2030 Revenue Use		
	Lump-Sum Rebates	Labor Tax Cuts	Electricity Subsidies	Lump-Sum Rebates	Labor Tax Cuts	Electricity Subsidies
Motor Vehicles	0.1%	0.1%	0.0%	0.2%	0.1%	0.1%
Furnishings and Household Equipment	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%
Recreation	0.1%	0.1%	0.0%	0.2%	0.1%	0.1%
Clothing	0.1%	0.1%	0.0%	0.2%	0.1%	0.1%
Health Care	0.2%	0.1%	0.0%	0.2%	0.1%	0.0%
Education	0.2%	0.1%	0.0%	0.2%	0.1%	0.0%
Communication	0.1%	0.1%	0.0%	0.2%	0.1%	0.0%
Food	0.1%	0.1%	0.0%	0.2%	0.1%	0.1%
Alcohol	0.1%	0.1%	0.0%	0.2%	0.1%	0.1%
Motor Vehicle Fuels (and lubricants and fluids)	6.2%	6.2%	6.2%	7.9%	7.8%	7.9%
Fuel Oil and Other Fuels	4.4%	4.3%	4.3%	5.6%	5.5%	5.5%
Personal Care	0.2%	0.1%	0.0%	0.2%	0.1%	0.0%
Tobacco	0.1%	0.1%	0.0%	0.2%	0.1%	0.1%
Housing	0.2%	0.2%	-0.1%	0.2%	0.1%	-0.1%
Water and Waste	0.2%	0.1%	0.0%	0.2%	0.1%	0.0%
Electricity	0.1%	0.0%	-9.3%	0.1%	0.0%	-11.9%
Natural Gas	6.0%	5.9%	6.0%	8.3%	8.2%	8.2%
Public Ground Transportation	0.6%	0.5%	0.5%	0.7%	0.7%	0.7%
Air Transportation	0.6%	0.6%	0.6%	0.8%	0.7%	0.7%
Water Transportation	0.6%	0.6%	0.6%	0.8%	0.7%	0.7%
Food Services and Accommodations	0.2%	0.1%	0.0%	0.2%	0.1%	0.0%
Financial Services and Insurance	0.2%	0.1%	0.0%	0.2%	0.1%	0.0%
Other Services	0.2%	0.1%	0.0%	0.2%	0.1%	0.1%
Net Foreign Travel	0.6%	0.6%	0.6%	0.8%	0.7%	0.7%
Consumer Price Index	**0.4%**	**0.3%**	**0.1%**	**0.5%**	**0.3%**	**0.1%**

Note: Carbon pricing design: WCI price path, transportation and heating fuels, Vermont only.

Aggregate Household Income. Figure 4.10 shows that revenue use options have a significant impact on real after-tax capital and labor income relative to BAU. Under lump-sum rebates, both capital and labor income fall in real terms, and capital income declines more than labor income. In contrast, reductions in taxes on wage earnings (i.e., labor tax cuts) increase both capital and labor income, and the increase in labor income is greater than the increase in capital income (because of the direct impact of a lower tax rate on wages). Under electricity rebates, labor income declines (despite the increase in labor demand due to a decline in wages), but capital income increases because of the positive impact of the policy on investment in the electric power sectors.

Figure 4.10. Percentage Change in Real Capital and Labor Income by Revenue Use



Change in Economic Welfare and Net Benefits. The change in total economic welfare caused by carbon pricing policies crucially depends on the use of carbon revenues. As displayed in Table 4.15, using revenues to reduce preexisting distortionary taxes may actually increase economic welfare, even ignoring climate and health benefits.

Table 4.15. Changes in Economic Welfare and Environmental Benefits by Revenue Use

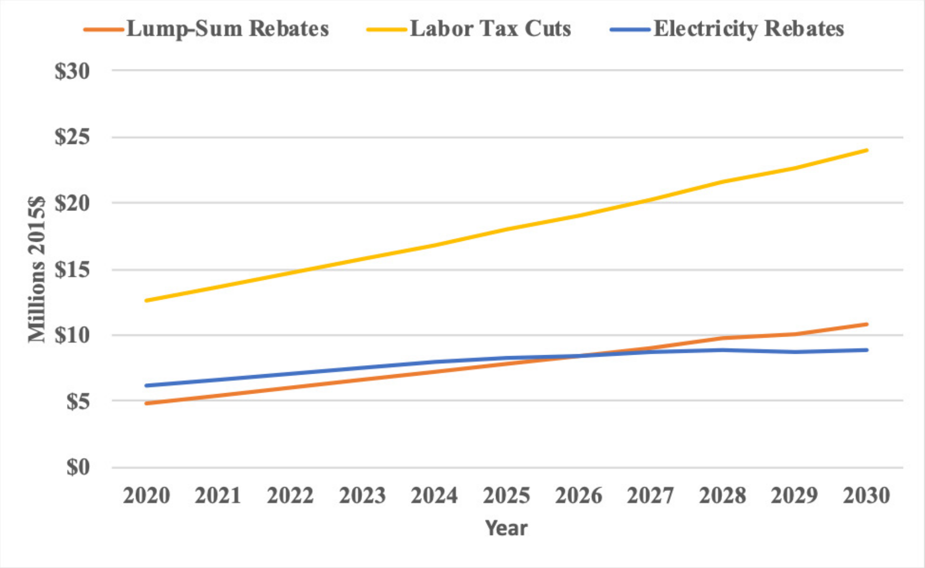
Revenue Use	Millions (2015$)								
	2020			2025			2030		
	Change in Economic Welfare	Climate Benefits	Health Benefits	Change in Economic Welfare	Climate Benefits	Health Benefits	Change in Economic Welfare	Climate Benefits	Health Benefits
Lump-Sum Rebates	-9.9	8.3	6.4	-12.1	11.4	8.5	-14.7	15.1	10.4
Labor Tax Cuts	0.4	8.2	4.1	1.1	11.3	5.5	2.4	15.0	6.7
Electricity Subsidies	-9.7	6.8	9.0	-9.8	8.5	9.5	-13.4	11.4	10.8

Note: Carbon pricing design: WCI price path, transportation and heating fuels, Vermont only.

Note: Economic welfare here represents the change in economic welfare across all households; a negative number implies households are worse off, in aggregate, than they would be with no carbon pricing policy.

While both the lump-sum rebates and electricity subsidies scenarios reduce total economic welfare, the labor tax cuts scenario (reductions in taxes on wage income) produces a positive change in overall economic welfare by reducing the distortionary tax on wage earnings.[65] The climate benefits are slightly lower under the electricity subsidies scenario because of slightly higher emissions (as discussed above). The health benefits from local air quality improvements are smallest under the labor tax cut scenario because of the economic stimulus provided by the reduction in taxes on wages. As shown in Figure 4.11, the net benefits (change in economic welfare plus environmental benefits) are positive in all years under all three revenue use options, but the net benefits are almost twice as large under the labor tax cut scenario than the lump-sum rebate scenario.

Figure 4.11. Net Benefits by Revenue Use



Distributional Impacts. The distributional impacts of carbon pricing crucially depend on the use of carbon revenues. Tables 4.16(a) – 4.16(c) display the change in economic welfare, in dollars per household, for each household income quintile in Vermont, broken down into the change associated with the consumption of commodities and the change associated with income. Again, these results consider only the welfare impacts in 2020 and they do not account for environmental benefits.

The lump-sum rebate more than offsets the burden of higher consumer good prices for the lower-income households, which results in positive economic welfare impacts for the two lowest quintiles. But this lump-sum rebate is a smaller percentage of income for higher-income households, resulting in increasingly negative economic welfare impacts for the three highest quintiles. The labor tax cut scenario has negative economic welfare impacts for the lowest three income quintiles and positive economic welfare impacts for the highest two quintiles. The economic welfare benefits associated with increased income (coming primarily from higher after-tax wages caused by the reduction in the tax on wages in this scenario) are similar for all five quintiles as a percentage of income (about 0.03 percent); for the lower income quintiles, the economic welfare costs associated with higher increased prices of consumption outweigh the income benefits (because lower-income households spend a larger fraction of their income on energy goods than higher-income households).

The electricity subsidies scenario has negative economic welfare impacts for the lower four quintiles and produces positive economic welfare impacts for only the top quintile. Compared with the other revenue recycling scenarios, the economic costs caused by changes in consumer prices are small for all quintiles (the lower price of electricity mostly offsets higher prices of the other energy goods). However, the economic welfare benefits associated with income are also small in this scenario, particularly for lower-income households, both in terms of cost per household and as a percentage of household income (because revenue is used to reduce electricity prices, which does not directly boost income, whereas the other two revenue uses directly boost income). Across all households and policy scenarios, the magnitude of economic welfare impacts is minor: the change in welfare is less than 0.1 percent of average household income for all income quintiles and policy scenarios.

Table 4.16(a). Change in Economic Welfare by Households (Income) under Lump-Sum Rebates, 2020

Economic Welfare Change by Quintile (2015$ per household)	1	2	3	4	5
Energy Goods	-76.51	-119.90	-177.19	-165.80	-247.45
Electricity	0.36	0.48	0.59	0.59	0.79
Fuel Oil and Other Fuels	-39.33	-55.57	-84.10	-63.10	-114.52
Motor Vehicle Fuels (and lubricants and fluids)	-34.38	-60.54	-88.72	-98.04	-126.60
Natural Gas	-3.16	-4.26	-4.97	-5.25	-7.12
Other Goods	-78.89	-111.24	-147.62	-165.25	-293.66
Sources of Income	251.90	266.42	286.70	316.16	289.69
Capital	1.69	3.15	7.82	14.70	73.57
Labor	15.73	36.71	72.98	125.97	247.72
Other Sources	234.48	226.55	205.89	175.49	-31.60
Total	**96.49**	**35.28**	**-38.12**	**-14.88**	**-251.42**

Note: Carbon pricing design: lump-sum rebates, WCI price path, transportation and heating sectors, Vermont only.

Table 4.16(b). Change in Economic Welfare by Households (Income) under Electricity Subsidies, 2020

Economic Welfare Change by Quintile (2015$ per household)	**1**	**2**	**3**	**4**	**5**
Energy Goods	-25.61	-52.71	-94.11	-82.83	-136.39
Electricity	50.73	66.86	82.48	82.48	110.20
Fuel Oil and Other Fuels	-39.02	-55.13	-83.44	-62.61	-113.62
Motor Vehicle Fuels (and lubricants and fluids)	-34.18	-60.20	-88.22	-97.49	-125.89
Natural Gas	-3.14	-4.24	-4.93	-5.21	-7.07
Other Goods	-2.86	-5.26	-8.41	-10.54	-22.67
Sources of Income	11.89	12.19	20.24	32.18	212.92
Capital	9.66	18.05	44.77	84.11	421.04
Labor	-2.00	-4.67	-9.28	-16.02	-31.50
Other Sources	4.24	-1.19	-15.25	-35.91	-176.62
Total	**-16.59**	**-45.77**	**-82.27**	**-61.19**	**53.87**

Note: Carbon pricing design: electricity subsidies, WCI price path, transportation and heating sectors, Vermont only.

Table 4.16(c). Change in Economic Welfare by Households (Income) under Labor Tax Cuts, 2020

Economic Welfare Change by Quintile (2015$ per household)	1	2	3	4	5
Energy Goods	-75.92	-119.06	-176.05	-164.72	-245.88
Electricity	0.59	0.78	0.96	0.96	1.29
Fuel Oil and Other Fuels	-39.16	-55.32	-83.73	-62.82	-114.02
Motor Vehicle Fuels (and lubricants and fluids)	-34.28	-60.36	-88.46	-97.76	-126.23
Natural Gas	-3.08	-4.15	-4.83	-5.11	-6.92
Other Goods	-50.73	-69.11	-90.22	-98.73	-173.13
Sources of Income	42.30	90.55	176.98	303.28	656.88
Capital	4.50	8.42	20.88	39.23	196.40
Labor	35.44	82.70	164.41	283.77	558.03
Other Sources	2.35	-0.57	-8.31	-19.72	-97.55
Total	**-84.35**	**-97.61**	**-89.30**	**39.83**	**237.87**

Note: Carbon pricing design: electricity subsidies, WCI price path, transportation and heating sectors, Vermont only.

The change in economic welfare for the average household in each county in Vermont, in dollars per household, is displayed in Tables 4.16(d) – 4.16(f). All counties have negative economic welfare impacts under the rebates scenario, one county has positive economic welfare impacts under the labor tax cut scenario, and two counties have positive economic welfare impacts under the electricity subsidies scenario. Under the lump-sum rebates scenario, rural counties with higher fuel oil and transportation expenditures tend to have greater economic welfare losses but those losses are partially offset by positive income effects, particularly in lower income counties. Under the electricity subsidies scenario, the subsidies somewhat offset increased energy expenditures but the counties with the highest home heating and transportation expenditures (such as Grand Isle, Essex, and Orleans Counties) still have the highest economic welfare losses. Chittenden County, with relatively low expenditures on home heating and transportation, is the only county with a positive change in economic welfare. Under the labor tax cut scenario, counties with the highest energy expenditure have the largest economic welfare losses. Additionally, lower income counties like Essex and Orleans Counties receive fewer income benefits than higher income counties. Only two counties, Chittenden and Grand Isle, have a positive change in economic welfare. As with the distributional results in the previous section, these county-level-mean estimates miss substantial within-county heterogeneity in changes in economic welfare. One would expect the pattern of results across income groups within each county to mirror the pattern of results across income groups at the state level (as previously discussed).

Table 4.16(d). Changes in Economic Welfare by County (Average Household) under Lump-Sum Rebates, 2020

Economic Welfare Change by County (2015$ per household)	Addison	Bennington	Caledonia	Chittenden	Essex	Franklin	Grand Isle	Lamoille	Orange	Orleans	Rutland	Washington	Windham	Windsor
Energy Goods	**-172.32**	**-172.65**	**-176.51**	**-123.45**	**-179.06**	**-170.57**	**-190.87**	**-159.83**	**-166.12**	**-167.06**	**-171.64**	**-164.40**	**-159.34**	**-168.71**
Electricity	0.64	0.62	0.54	0.53	0.47	0.63	0.51	0.54	0.53	0.46	0.59	0.55	0.57	0.60
Fuel Oil and Other Fuels	-86.46	-92.27	-88.72	-36.03	-86.48	-74.41	-89.79	-75.31	-77.18	-83.05	-90.65	-83.03	-76.68	-80.91
Motor Vehicle Fuels (and lubricants and fluids)	-86.01	-80.40	-88.02	-71.46	-92.86	-89.42	-100.85	-84.63	-89.00	-84.30	-81.21	-81.33	-82.90	-87.76
Natural Gas	-0.48	-0.60	-0.31	-16.50	-0.19	-7.37	-0.74	-0.43	-0.48	-0.18	-0.38	-0.59	-0.34	-0.64
Other Goods	**-162.99**	**-153.32**	**-145.84**	**-173.31**	**-131.83**	**-161.80**	**-166.24**	**-155.41**	**-156.03**	**-141.09**	**-149.16**	**-161.26**	**-150.16**	**-158.90**
Sources of Income	**283.50**	**282.39**	**278.67**	**284.80**	**273.99**	**282.54**	**287.79**	**281.17**	**280.63**	**276.79**	**279.58**	**282.39**	**280.48**	**283.54**
Capital	20.94	18.18	14.70	26.12	10.61	20.39	23.77	18.47	17.75	13.41	16.10	20.52	16.54	20.50
Labor	103.37	94.85	81.41	118.38	65.20	100.79	115.83	94.17	91.67	75.79	86.12	100.96	88.33	102.25
Other Sources	159.20	169.36	182.56	140.31	198.18	161.36	148.19	168.52	171.21	187.59	177.35	160.91	175.61	160.79
Total	**-51.80**	**-43.58**	**-43.67**	**-11.96**	**-36.90**	**-49.84**	**-69.32**	**-34.07**	**-41.53**	**-31.36**	**-41.22**	**-43.26**	**-29.02**	**-44.08**

Note: Carbon pricing design: lump-sum rebates, WCI price path, transportation and heating sectors, Vermont only.

Table 4.16(e). Changes in Economic Welfare by County (Average Household) under Electricity Subsidies, 2020

Economic Welfare Change by County (2015$ per household)	Addison	Bennington	Caledonia	Chittenden	Essex	Franklin	Grand Isle	Lamoille	Orange	Orleans	Rutland	Washington	Windham	Windsor
Energy Goods	**-83.26**	**-85.83**	**-100.28**	**-48.79**	**-112.89**	**-82.63**	**-119.75**	**-83.88**	**-91.40**	**-102.20**	**-88.34**	**-87.35**	**-79.68**	**-84.77**
Electricity	88.53	86.26	75.58	74.40	65.44	87.44	70.35	75.42	74.14	64.20	82.72	76.49	79.16	83.41
Fuel Oil and Other Fuels	-85.78	-91.55	-88.02	-35.74	-85.80	-73.82	-89.08	-74.72	-76.57	-82.40	-89.94	-82.38	-76.08	-80.27
Motor Vehicle Fuels (and lubricants and fluids)	-85.53	-79.94	-87.53	-71.05	-92.34	-88.92	-100.28	-84.16	-88.49	-83.83	-80.75	-80.87	-82.43	-87.27
Natural Gas	-0.47	-0.60	-0.30	-16.39	-0.19	-7.32	-0.74	-0.43	-0.48	-0.17	-0.37	-0.59	-0.33	-0.63
Other Goods	**-10.27**	**-9.37**	**-8.68**	**-11.26**	**-7.38**	**-10.17**	**-10.57**	**-9.59**	**-9.62**	**-8.25**	**-9.00**	**-10.13**	**-9.09**	**-9.90**
Sources of Income	**59.73**	**51.91**	**42.72**	**74.61**	**31.98**	**58.38**	**66.86**	**53.12**	**51.16**	**39.43**	**46.59**	**58.81**	**47.62**	**58.42**
Capital	119.84	104.04	84.15	149.46	60.73	116.69	136.04	105.72	101.61	76.73	92.17	117.44	94.66	117.30
Labor	-13.14	-12.06	-10.35	-15.05	-8.29	-12.82	-14.73	-11.97	-11.66	-9.64	-10.95	-12.84	-11.23	-13.00
Other Sources	-46.96	-40.06	-31.08	-59.80	-20.46	-45.49	-54.45	-40.62	-38.80	-27.66	-34.62	-45.80	-35.81	-45.88
Total	**-33.80**	**-43.29**	**-66.24**	**14.55**	**-88.28**	**-34.41**	**-63.45**	**-40.35**	**-49.87**	**-71.02**	**-50.75**	**-38.67**	**-41.14**	**-36.26**

Note: Carbon pricing design: electricity subsidies, WCI price path, transportation and heating sectors, Vermont only.

Table 4.16(f). Changes in Economic Welfare by County (Average Household) under Labor Tax Cuts, 2020

Economic Welfare Change by County (2015$ per household)	Addison	Bennington	Caledonia	Chittenden	Essex	Franklin	Grand Isle	Lamoille	Orange	Orleans	Rutland	Washington	Windham	Windsor
Energy Goods	**-171.27**	**-171.60**	**-175.51**	**-122.30**	**-178.10**	**-169.39**	**-189.84**	**-158.90**	**-165.17**	**-166.15**	**-170.62**	**-163.43**	**-158.39**	**-167.70**
Electricity	1.03	1.01	0.88	0.87	0.76	1.02	0.82	0.88	0.87	0.75	0.97	0.89	0.93	0.98
Fuel Oil and Other Fuels	-86.08	-91.86	-88.33	-35.87	-86.09	-74.08	-89.39	-74.98	-76.84	-82.68	-90.25	-82.66	-76.34	-80.55
Motor Vehicle Fuels (and lubricants and fluids)	-85.76	-80.16	-87.77	-71.25	-92.59	-89.16	-100.55	-84.38	-88.73	-84.05	-80.97	-81.09	-82.66	-87.51
Natural Gas	-0.46	-0.58	-0.30	-16.05	-0.19	-7.17	-0.72	-0.42	-0.47	-0.17	-0.37	-0.57	-0.33	-0.62
Other Goods	**-98.45**	**-92.98**	**-88.69**	**-104.34**	**-80.75**	**-97.78**	**-100.30**	**-94.14**	**-94.51**	**-86.02**	**-90.60**	**-97.48**	**-91.16**	**-96.15**
Sources of Income	**262.88**	**240.15**	**205.53**	**303.42**	**163.95**	**256.41**	**294.39**	**239.08**	**232.52**	**191.31**	**217.94**	**256.98**	**223.43**	**259.77**
Capital	55.90	48.53	39.25	69.72	28.33	54.43	63.46	49.31	47.40	35.79	42.99	54.78	44.16	54.72
Labor	232.86	213.68	183.38	266.66	146.86	227.04	260.93	212.14	206.49	170.74	194.01	227.43	198.99	230.33
Other Sources	-25.87	-22.06	-17.10	-32.96	-11.25	-25.06	-30.00	-22.37	-21.36	-15.22	-19.06	-25.23	-19.71	-25.27
Total	**-6.84**	**-24.43**	**-58.66**	**76.78**	**-94.91**	**-10.76**	**4.25**	**-13.96**	**-27.16**	**-60.87**	**-43.28**	**-3.93**	**-26.12**	**-4.08**

Note: Carbon pricing design: labor tax reductions, WCI price path, transportation and heating sectors, Vermont only.

4.5. Sectoral Coverage

The economic and environmental impacts of carbon pricing policies generally increase as the number of sectors and fuels covered by the carbon price increase. And although the economic costs are also increasing in the number of sectors covered, the economic costs per ton reduced are decreasing in the number of sectors covered; in other words, policies that cover more sectors are more cost-effective than policies that cover fewer sectors.

In the analysis in the two preceding sections, we considered both economy-wide (electricity exempt) policies and policies that covered both transportation and heating fuel. In this section, we also consider the impacts of policy that covers only transportation fuels. We do not consider policies that cover non-CO_2 greenhouse gas emissions.[66]

- *Economy-Wide (electricity exempt)*. Carbon dioxide emissions from the transportation, residential, commercial, and industrial sectors are covered.
- *Transportation and Heating*. Transportation carbon dioxide emissions and carbon dioxide emissions from residential and commercial use of heating fuels are covered.
- *Transportation Only*. This policy covers transportation carbon dioxide emissions only. Transportation emissions include emissions from household purchases of motor vehicle fuels and the transportation sector's purchase of refined petroleum products.

Because Vermont is a member of RGGI, we do not consider any policies that cover electricity emissions (from consumption).[67] In this section, all policies use the WCI price, lump-sum rebates, and cover Vermont emissions only.

4.5.1. Environmental Impacts

GHG Emissions Levels. Figure 4.12 displays historical and projected greenhouse gas emissions for the state of Vermont from 2015 to 2030 under business as usual and the three sectoral coverage options. Emissions reductions relative to BAU are increasing in the number of sectors covered, but on an absolute basis, there is little difference in Vermont's GHG emissions levels across the coverage options. On a relative basis, however, the emissions reductions under transportation only are approximately 35 percent smaller than the reductions under the other two options. Because the Vermont carbon price does not significantly reduce industrial emissions, the emissions impacts from economy-wide (electricity exempt) and transportation and heating are very similar. Table 4.17 displays the emissions projections across sectors in 2025 and 2030.

Figure 4.12. Vermont GHG Emissions by Sectoral Coverage (Carbon Pricing Only)

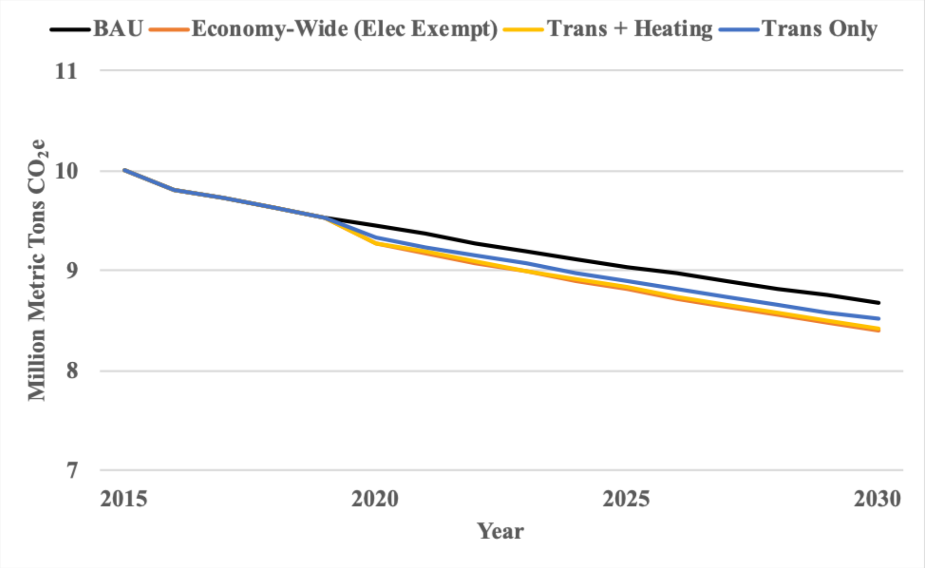


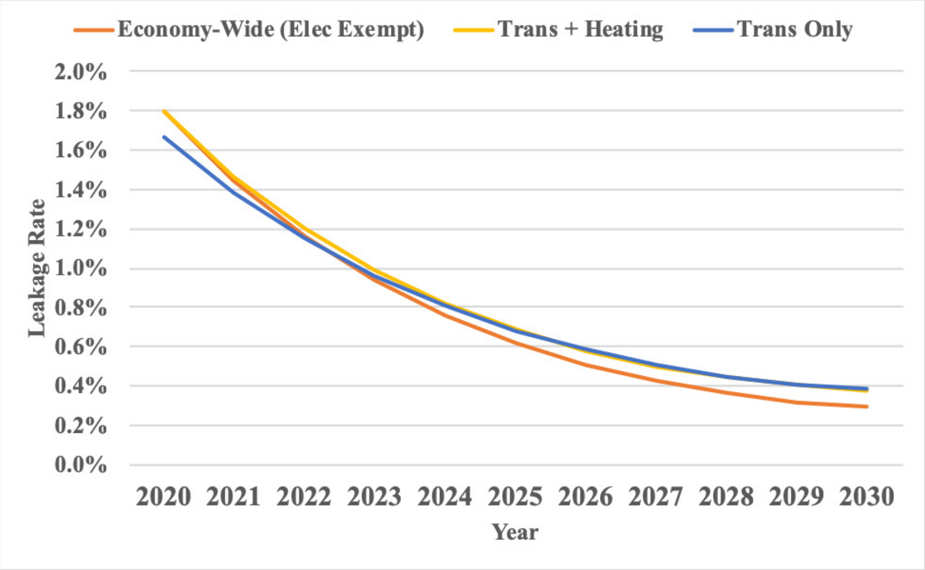
Table 4.17. Vermont GHG Emissions by Sector by Sectoral Coverage (Carbon Pricing Only)

Million Metric Tons CO_2 Equivalent ($MMTCO_2e$)									
	2015	2025				2030			
	Historical		Sectoral Coverage				Sectoral Coverage		
Sector		BAU	Economy-Wide (electricity exempt)	Transport and Heating Fuels	Transport only	BAU	Economy-Wide (electricity exempt)	Transport and Heating Fuels	Transport only
Electricity (consumption based)	1.0	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6
Residential/ Commercial/Industrial Fuel Use	2.8	2.5	2.4	2.4	2.5	2.4	2.3	2.3	2.4
Transportation	4.3	4.0	3.8	3.8	3.8	3.8	3.6	3.6	3.6
Fossil Fuel Industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial Processes	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Waste Management	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Agriculture	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Total	**10.0**	**9.1**	**8.8**	**8.8**	**8.9**	**8.7**	**8.4**	**8.4**	**8.5**
Total Relative to 1990	**16%**	**6%**	**3%**	**3%**	**4%**	**1%**	**-2%**	**-2%**	**-1%**
Total Relative to 2005	**-2%**	**-11%**	**-14%**	**-14%**	**-13%**	**-15%**	**-18%**	**-18%**	**-17%**

Note: Carbon pricing design: WCI price path, lump-sum rebates, Vermont only.

Figure 4.13 shows that the patterns of emissions leakage to Northeast states are similar across the three coverage options. In all cases, the increase in emissions in other Northeast states due to Vermont's carbon policy is small. The transportation only policy displays slightly less leakage in the short run and slightly more leakage in the long run.

Figure 4.13. Leakage to Northeast States by Sectoral Coverage



Criteria Air Pollutants. Table 4.18 reports the changes in local criteria air pollutant emissions in Vermont across the three coverage scenarios. The level of reductions in these emissions significantly depends on the coverage of the policy. Moving from the economy-wide (electricity exempt) policy to transportation and heating fuels policy removes reductions associated with industrial processes and fuel use; carbon monoxide, nitrogen oxide, and volatile organic compounds emissions are most affected. Exempting heating fuels reduces the level of reductions of each of those three pollutants as well as emissions of sulfur dioxide and ammonia.

Table 4.18. Percentage Change in Criteria Air Pollutant Emissions by Sectoral Coverage

BAU and Historical:1000 tons; Carbon Pricing: Percentage Change from BAU								
	2015	2025				2030		
	Historical		Sectoral Coverage				Sectoral Coverage		
Criteria Air Pollutant		BAU	Economy-Wide (electricity exempt)	Transport and Heating Fuels	Transport only	BAU	Economy-Wide (electricity exempt)	Transport and Heating Fuels	Transport only
Carbon Monoxide (CO)	135.8	122.9	-2.1%	-1.6%	-0.9%	118.3	-2.6%	-2.0%	-1.2%
Nitrogen Oxide (NOx)	15.5	14.1	-3.4%	-3.0%	-2.1%	13.5	-4.3%	-3.8%	-2.7%
Particulate Matter 10 (PM10)	10.3	9.1	-0.3%	-0.3%	-0.2%	8.9	-0.4%	-0.4%	-0.3%
Particulate Matter 2.5 (PM2.5)	9.0	8.0	-0.2%	-0.1%	-0.1%	7.8	-0.3%	-0.2%	-0.1%
Sulfur Dioxide (SO2)	1.4	1.3	-2.3%	-2.2%	-1.2%	1.2	-2.9%	-2.7%	-1.5%
Volatile Organic Compounds (VOC)	19.6	17.7	-1.7%	-1.0%	-0.6%	17.0	-2.1%	-1.3%	-0.8%
Ammonia (NH3)	0.7	0.6	-2.0%	-1.9%	-0.9%	0.6	-2.5%	-2.4%	-1.1%

4.5.2. Economic Impacts

Gross Carbon Revenue. Table 4.19 displays the annual gross carbon revenues across the three coverage options. The level of revenue is increasing in the scope of the policy. Because Vermont has relatively low levels of industrial carbon dioxide emissions, the carbon revenue is not significantly different between the economy-wide (electricity exempt) and transportation and heating policies. The transportation only policy raises about 65 percent of the revenue raised by the transportation and heating policy.

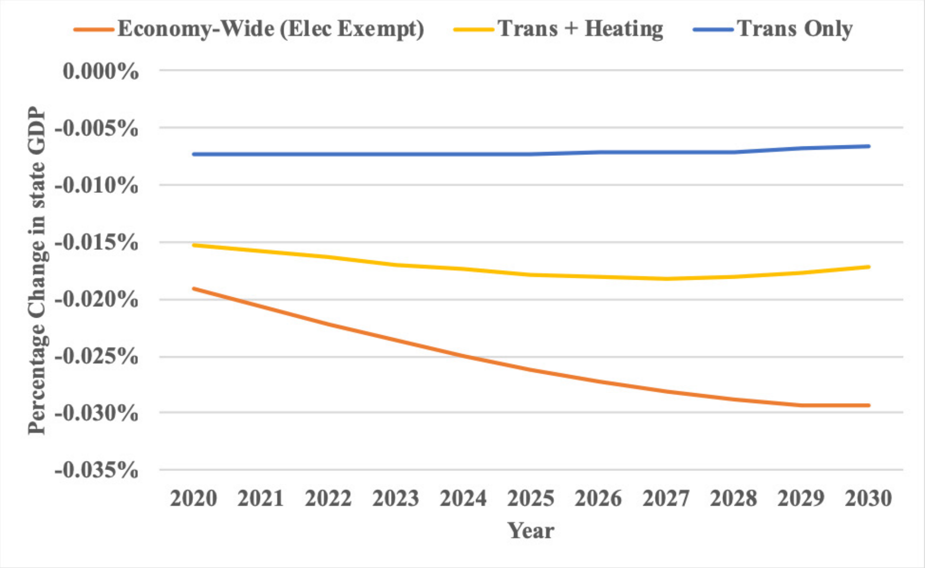
Table 4.19. Annual Gross Carbon Revenues by Sectoral Coverage

	Millions (2015$)		
Sectoral Coverage	**2020**	**2025**	**2030**
Economy-Wide (electricity exempt)	99.4	120.8	147.0
Transportation and Heating	94.1	114.3	138.9
Transportation Only	62.1	74.7	89.6

Note: Carbon pricing design: WCI price path, lump-sum rebates, Vermont only.

Macroeconomic Impacts. The impact of Vermont carbon pricing policies on the state economy, as measured through state GDP, is increasing in the number of sectors covered (Figure 4.14). In all cases, the absolute change in state GDP is small (as a result of the relatively low WCI price path), but the relative difference between the policies is large. The state GDP impact of transportation and heating is approximately 2.5 times larger than the impact of transportation only, and the impact of economy-wide (electricity exempt) is about 1.5 times larger than the impact of the transportation and heating policy.

Figure 4.14. Percentage Change in Vermont GDP by Sectoral Coverage



The impacts of the carbon price by sector vary across the sectoral coverage option, although the differences are small in absolute value for each industry. Table 4.20 reports the percentage change in output by industry across the three options. In aggregate, the output changes are greatest in the economy-wide (electricity exempt) coverage and smallest under the transportation only policy. Notably, natural gas distribution experiences no adverse impacts if heating fuels are not included in the carbon pricing policy, but relatively large impacts if heating fuels are included. The impacts on farm, forestry, and fishing output, which in Vermont represents the agriculture and timber industries, are similar across the different coverage scenarios.

Table 4.20. Percentage Change in Industry Output by Sectoral Coverage

Industry	2025 Sectoral Coverage			2030 Sectoral Coverage		
	Economy-Wide (electricity exempt)	Transport and Heating Fuels	Transport only	Economy-Wide (electricity exempt)	Transport and Heating Fuels	Transport only
Electricity Generation	-0.1%	-0.1%	0.0%	-0.2%	-0.1%	0.0%
Electric Transmission and Distribution	-0.4%	-0.2%	0.1%	-0.6%	-0.3%	0.1%
Natural Gas Distribution	-3.8%	-3.7%	0.0%	-5.1%	-5.0%	0.1%
Other Mining and Mining Services	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Farms, Forestry, Fishing	-0.1%	-0.1%	-0.1%	-0.2%	-0.1%	-0.1%
Construction	-0.6%	-0.6%	-0.6%	-0.7%	-0.7%	-0.7%
Nondurable Manufacturing	-0.1%	-0.1%	-0.1%	-0.2%	-0.1%	-0.1%
Chemicals, Plastics, Rubber, and Nonmetallic Mineral Products	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Durable Manufacturing	-0.1%	0.0%	0.0%	-0.1%	-0.1%	0.0%
Trade	-0.1%	-0.1%	0.0%	-0.2%	-0.1%	-0.1%
Transportation	-0.2%	-0.1%	-0.1%	-0.2%	-0.2%	-0.1%
Communication and Information	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%
Services	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Real Estate and Owner-Occupied Housing	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%
All Industries	**-0.05%**	**-0.03%**	**-0.02%**	**-0.06%**	**-0.04%**	**-0.02%**

Note: Carbon pricing design: WCI price path, lump-sum rebates, Vermont only.

Labor Demand Impacts. Again, the labor demand impacts across sectors largely mirror the impacts on output by sector, with the aggregate impacts increasing in the level of sectoral coverage (Table 4.21). Only a few sectors are projected to experience declines in labor demand under a transportation only policy. The difference in labor demand between transportation and heating and economy-wide (electricity exempt) is negligible. Again, the effect on natural gas distribution depends strongly on whether heating fuels are included under the carbon price.

Table 4.21. Percentage Change in Labor Demand by Sectoral Coverage

Industry	2025 Sectoral Coverage			2030 Sectoral Coverage		
	Economy-Wide (electricity exempt)	Transport and Heating Fuels	Transport only	Economy-Wide (electricity exempt)	Transport and Heating Fuels	Transport only
Electricity Generation	-0.2%	-0.1%	0.0%	-0.2%	-0.2%	0.0%
Electric Transmission and Distribution	-0.6%	-0.4%	0.0%	-0.7%	-0.5%	0.0%
Natural Gas Distribution	-4.3%	-4.2%	0.0%	-5.5%	-5.4%	0.0%
Other Mining and Mining Services	0.0%	-0.1%	0.0%	0.0%	-0.1%	0.0%
Farms, Forestry, Fishing	-0.2%	-0.2%	-0.1%	-0.2%	-0.2%	-0.1%
Construction	0.1%	0.1%	0.2%	0.2%	0.2%	0.3%
Nondurable Manufacturing	-0.1%	-0.1%	-0.1%	-0.1%	-0.2%	-0.1%
Chemicals, Plastics, Rubber, and Nonmetallic Mineral Products	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Durable Manufacturing	-0.1%	-0.1%	0.0%	-0.1%	-0.1%	0.0%
Trade	-0.1%	-0.1%	-0.1%	-0.2%	-0.2%	-0.1%
Transportation	-0.2%	-0.2%	-0.1%	-0.3%	-0.3%	-0.1%
Communication and Information	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Services	0.0%	0.1%	0.0%	0.1%	0.1%	0.0%
Real Estate and Owner-Occupied Housing	0.1%	0.1%	0.0%	0.1%	0.1%	0.0%
All Industries	**-0.02%**	**-0.02%**	**-0.01%**	**-0.02%**	**-0.02%**	**-0.01%**

Note: Carbon pricing design: WCI price path, lump-sum rebates, Vermont only.

Consumer Prices. The impact on consumer prices is increasing in sectoral coverage (Table 4.22). Under a transportation only policy, substantial price impacts are concentrated entirely in motor vehicle fuels, with smaller impacts in transportation-related consumer goods such as public ground, air, and water transportation and net foreign travel. Not surprisingly, including heating fuels in the carbon price substantially increases the price of fuel oil.

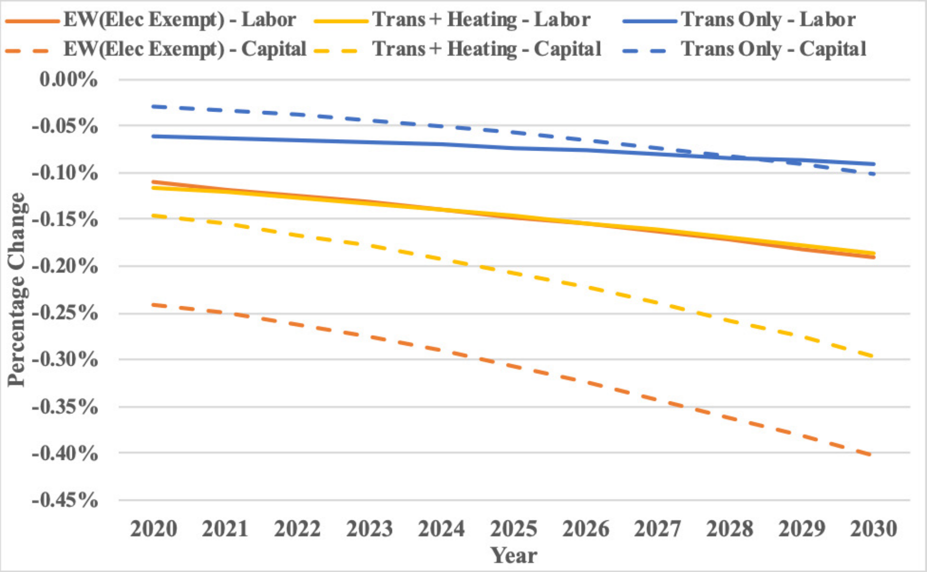
Table 4.22. Percentage Change in Consumer Prices by Sectoral Coverage

Consumer Good	2025 Sectoral Coverage			2030 Sectoral Coverage		
	Economy-Wide (electricity exempt)	Transport and Heating Fuels	Transport only	Economy-Wide (electricity exempt)	Transport and Heating Fuels	Transport only
Motor Vehicles	0.2%	0.1%	0.1%	0.2%	0.2%	0.1%
Furnishings and Household Equipment	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%
Recreation	0.2%	0.1%	0.1%	0.2%	0.2%	0.1%
Clothing	0.2%	0.1%	0.1%	0.2%	0.2%	0.1%
Health Care	0.2%	0.2%	0.1%	0.2%	0.2%	0.1%
Education	0.2%	0.2%	0.1%	0.2%	0.2%	0.1%
Communication	0.1%	0.1%	0.1%	0.2%	0.2%	0.1%
Food	0.2%	0.1%	0.1%	0.2%	0.2%	0.1%
Alcohol	0.2%	0.1%	0.1%	0.2%	0.2%	0.1%
Motor Vehicle Fuels (and lubricants and fluids)	6.2%	6.2%	6.2%	7.9%	7.9%	7.9%
Fuel Oil and Other Fuels	4.4%	4.4%	0.0%	5.6%	5.6%	0.0%
Personal Care	0.2%	0.2%	0.1%	0.2%	0.2%	0.1%
Tobacco	0.2%	0.1%	0.1%	0.2%	0.2%	0.1%
Housing	0.2%	0.2%	0.1%	0.2%	0.2%	0.1%
Water and Waste	0.2%	0.2%	0.1%	0.2%	0.2%	0.1%
Electricity	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%
Natural Gas	6.0%	6.0%	0.1%	8.3%	8.3%	0.1%
Public Ground Transportation	0.6%	0.6%	0.5%	0.8%	0.7%	0.7%
Air Transportation	0.6%	0.6%	0.6%	0.8%	0.8%	0.7%
Water Transportation	0.6%	0.6%	0.6%	0.8%	0.8%	0.7%
Food Services and Accommodations	0.2%	0.2%	0.1%	0.2%	0.2%	0.1%
Financial Services and Insurance	0.2%	0.2%	0.1%	0.2%	0.2%	0.1%
Other Services	0.2%	0.2%	0.1%	0.3%	0.2%	0.1%
Net Foreign Travel	0.6%	0.6%	0.6%	0.8%	0.8%	0.7%
Consumer Price Index	**0.39%**	**0.37%**	**0.18%**	**0.49%**	**0.46%**	**0.23%**

Note: Carbon pricing design: WCI price path, lump-sum rebates, Vermont only.

Aggregate Household Income. The change in real labor income is similar under both the economy-wide (electricity exempt) and the transportation and heating policies, but under the transportation only policy it is approximately half as large as under the other two coverage scenarios (Figure 4.15). For real capital income, the change relative to BAU is increasing in the number of sectors covered and represents the relative capital intensity of the covered sectors. Transportation is not especially capital-intensive, and therefore the impacts on capital income are similar to impacts on labor income. Heating fuels are more capital-intensive, especially natural gas distribution, and therefore the impacts on capital income are larger. Finally, industry is especially capital-intensive, and therefore the impacts on capital income are much larger under the policy that covers industrial emissions than under policies that do not cover industrial emissions.

Figure 4.15. Percentage Change in Real Capital and Labor Income by Sectoral Coverage



Change in Economic Welfare and Net Benefits. Both the cost (i.e., decrease in economic welfare) and the environmental benefits of Vermont carbon pricing policies are increasing in the number of sectors covered by the price (Table 4.23). The transportation only policy is the least costly (i.e., causes the smallest decrease in economic welfare) but delivers the lowest value of climate and health benefits. Adding heating fuels to the policy increases the magnitude of the decrease in economic welfare by about 70 percent and the climate benefits by about 50 percent. Adding industrial emissions to the carbon pricing policy increases the magnitude of the decrease in economic welfare and climate benefits by about 5 and 7 percent, respectively, but increases the nonclimate health benefits by about 30 percent, relative to the transportation and heating scenario.

Table 4.23. Changes in Economic Welfare and Environmental Benefits by Sectoral Coverage

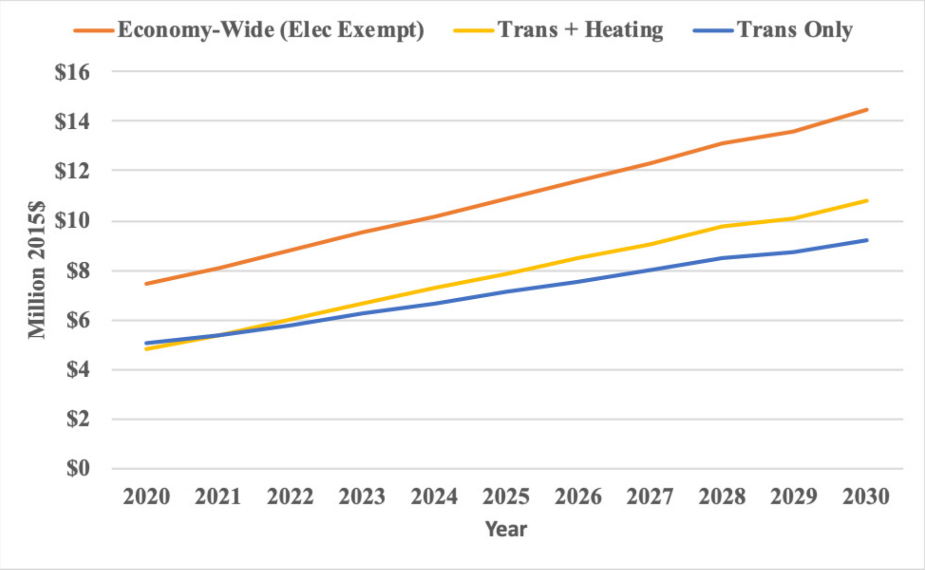
	Millions (2015$)								
	2020			2025			2030		
Sectoral Coverage	Change in Economic Welfare	Climate Benefits	Health Benefits	Change in Economic Welfare	Climate Benefits	Health Benefits	Change in Economic Welfare	Climate Benefits	Health Benefits
Economy-Wide (electricity exempt)	-10.0	8.9	8.5	-12.7	12.3	11.3	-15.7	16.3	13.8
Transportation and Heating Fuels	-9.9	8.3	6.4	-12.1	11.4	8.5	-14.7	15.1	10.4
Transportation Only	-5.9	5.7	5.2	-7.1	7.5	6.7	-8.6	9.8	8.1

Note: Carbon pricing design: WCI price path, lump-sum rebates, Vermont only.

Note: Economic welfare here represents the change in economic welfare across all households; a negative number implies households are worse off, in aggregate, than they would be with no carbon pricing policy.

As shown in Figure 4.16, each policy scenario delivers positive net benefits that are increasing over time. And the more sectors that are covered, the larger the net benefits will be.

Figure 4.16. Net Benefits by Sectoral Coverage



Distributional Impacts. The change in economic welfare across different types of households will vary by the number of fuels and sectors covered by a carbon pricing policy. Tables 4.24(a) – 4.24(c) display the changes in economic welfare, in dollars per household, for each household income quintile in Vermont, broken down into the changes caused by changes in consumer prices and the changes caused by changes in income. As with the distributional results in other sections, these results consider only the welfare impacts in 2020 and they do not account for environmental benefits.

In all three sectoral coverage scenarios, the change in economic welfare increases for the two lowest-income quintiles and decreases for the three highest-income quintiles. This is because all three scenarios include lump-sum rebates, which disproportionately benefit lower-income households. In the scenarios with greater sectoral coverage, all the effects are larger: the positive change in economic welfare for lower-income households are higher, and the negative change in economic welfare for higher-income households are higher as well. This is because the costs caused by higher consumer good prices increase as more sectors face a carbon price, but broader coverage also increases revenues and raises lump-sum rebates. Across all households and policy scenarios, the magnitude of economic welfare impacts is minor: the change in economic welfare is less than 0.1 percent of average household income for all income quintiles and policy scenarios.

Table 4.24(a). Change in Economic Welfare by Households (Income) under Economy-Wide Sector Coverage (Electricity Exempt), 2020

Economic Welfare Change by Quintile (2015$ per household)	**1**	**2**	**3**	**4**	**5**
Energy Goods	-75.83	-119.03	-176.19	-164.75	-246.11
Electricity	1.12	1.48	1.82	1.82	2.43
Fuel Oil and Other Fuels	-39.42	-55.69	-84.29	-63.24	-114.77
Motor Vehicle Fuels (and lubricants and fluids)	-34.43	-60.64	-88.85	-98.19	-126.80
Natural Gas	-3.10	-4.18	-4.86	-5.14	-6.97
Other Goods	-86.90	-122.65	-162.40	-182.25	-322.18
Sources of Income	282.26	296.51	313.71	338.63	249.53
Capital	0.85	1.59	3.95	7.42	37.16
Labor	17.42	40.65	80.81	139.48	274.29
Other Sources	263.99	254.26	228.95	191.72	-61.93
Total	**119.54**	**54.82**	**-24.88**	**-8.38**	**-318.76**

Note: Carbon pricing design: economy-wide (electricity exempt), WCI price path, lump-sum rebates, Vermont only.

Table 4.24(b). Change in Economic Welfare by Households (Income) under Transportation and Heating Sector Coverage, 2020

Economic Welfare Change by Quintile (2015$ per household)	1	2	3	4	5
Energy Goods	-76.51	-119.90	-177.19	-165.80	-247.45
Electricity	0.36	0.48	0.59	0.59	0.79
Fuel Oil and Other Fuels	-39.33	-55.57	-84.10	-63.10	-114.52
Motor Vehicle Fuels (and lubricants and fluids)	-34.38	-60.54	-88.72	-98.04	-126.60
Natural Gas	-3.16	-4.26	-4.97	-5.25	-7.12
Other Goods	-78.89	-111.24	-147.62	-165.25	-293.66
Sources of Income	251.90	266.42	286.70	316.16	289.69
Capital	1.69	3.15	7.82	14.70	73.57
Labor	15.73	36.71	72.98	125.97	247.72
Other Sources	234.48	226.55	205.89	175.49	-31.60
Total	**96.49**	**35.28**	**-38.12**	**-14.88**	**-251.42**

Note: Carbon pricing design: transportation and heating sector, WCI price path, lump-sum rebates, Vermont only.

Table 4.24(c). Change in Economic Welfare by Households (Income) under Transportation Sector Coverage, 2020

Economic Welfare Change by Quintile (2015$ per household)	**1**	**2**	**3**	**4**	**5**
Energy Goods	-35.24	-61.68	-90.18	-99.34	-128.58
Electricity	-0.49	-0.65	-0.80	-0.80	-1.07
Fuel Oil and Other Fuels	-0.30	-0.43	-0.64	-0.48	-0.88
Motor Vehicle Fuels (and lubricants and fluids)	-34.29	-60.38	-88.48	-97.78	-126.27
Natural Gas	-0.16	-0.22	-0.25	-0.27	-0.36
Other Goods	-37.93	-53.36	-70.72	-79.38	-140.90
Sources of Income	125.98	132.87	142.63	156.83	147.87
Capital	1.32	2.47	6.12	11.50	57.58
Labor	7.57	17.66	35.11	60.59	119.16
Other Sources	117.09	112.74	101.40	84.73	-28.87
Total	**52.81**	**17.83**	**-18.27**	**-21.89**	**-121.62**

Note: Carbon pricing design: transportation sector, WCI price path, lump-sum rebates, Vermont only.

Tables 4.24(d) – 4.24(f) display the changes in economic welfare, in dollars per household, for the average household in each county in Vermont. The change in economic welfare is negative for all counties in all scenarios, because the mean households in each county are in the third- and fourth-income quintiles, which tend to have negative changes in economic welfare under lump-sum rebate policies. Rural counties with higher home heating and transportation expenditures have greater consumption-related impacts, which are only partially offset by income benefits from the lump-sum rebates, which are most beneficial for lower income counties. Chittenden County, with low home heating and transportation expenditures, has the smallest change in economic welfare and Grand Isle, with high home heating and transportation expenditures and high income, has the largest change in economic welfare in all three scenarios. The scenarios with higher sectoral coverage have greater magnitude of changes in economic welfare because the costs of energy consumption increase. As with the distributional results in previous sections, these county-level-mean estimates miss substantial within-county heterogeneity in economic welfare. One would expect the pattern of results across income groups within each county to mirror the pattern of results across income groups at the state level (as just discussed).

Table 4.24(d). Changes in Economic Welfare by County (Average Household) under Economy-Wide (Electricity Exempt) Coverage, 2020

Economic Welfare Change by County (2015$ per household)	**Addison**	**Bennington**	**Caledonia**	**Chittenden**	**Essex**	**Franklin**	**Grand Isle**	**Lamoille**	**Orange**	**Orleans**	**Rutland**	**Washington**	**Windham**	**Windsor**
Energy Goods	**-171.31**	**-171.68**	**-175.71**	**-122.19**	**-178.42**	**-169.42**	**-190.16**	**-159.00**	**-165.32**	**-166.42**	**-170.73**	**-163.56**	**-158.45**	**-167.77**
Electricity	1.95	1.90	1.67	1.64	1.44	1.93	1.55	1.66	1.64	1.42	1.83	1.69	1.75	1.84
Fuel Oil and Other Fuels	-86.65	-92.47	-88.91	-36.11	-86.67	-74.57	-89.98	-75.48	-77.35	-83.23	-90.85	-83.21	-76.85	-81.09
Motor Vehicle Fuels (and lubricants and fluids)	-86.15	-80.52	-88.16	-71.57	-93.00	-89.56	-101.01	-84.76	-89.13	-84.43	-81.33	-81.45	-83.03	-87.90
Natural Gas	-0.47	-0.59	-0.30	-16.16	-0.19	-7.22	-0.72	-0.42	-0.47	-0.17	-0.37	-0.58	-0.33	-0.62
Other Goods	**-179.30**	**-168.69**	**-160.50**	**-190.59**	**-145.14**	**-177.99**	**-182.87**	**-170.98**	**-171.67**	**-155.28**	**-164.13**	**-177.39**	**-165.23**	**-174.80**
Sources of Income	**296.80**	**298.42**	**297.96**	**292.90**	**297.07**	**296.31**	**298.55**	**296.80**	**296.95**	**297.24**	**297.50**	**296.03**	**298.03**	**297.29**
Capital	10.58	9.18	7.43	13.19	5.36	10.30	12.01	9.33	8.97	6.77	8.14	10.37	8.36	10.35
Labor	114.46	105.03	90.14	131.08	72.19	111.60	128.26	104.27	101.50	83.92	95.36	111.79	97.81	113.21
Other Sources	171.76	184.21	200.39	148.63	219.52	174.41	158.28	183.19	186.48	206.55	194.00	173.87	191.87	173.72
Total	**-53.81**	**-41.95**	**-38.25**	**-19.88**	**-26.48**	**-51.09**	**-74.48**	**-33.18**	**-40.04**	**-24.45**	**-37.35**	**-44.92**	**-25.65**	**-45.28**

Note: Carbon pricing design: economy-wide (electricity exempt), WCI price path, lump-sum rebates, Vermont only.

Table 4.24(e). Changes in Economic Welfare by County (Average Household) under Transportation and Heating Coverage, 2020

Economic Welfare Change by County (2015$ per household)	**Addison**	**Bennington**	**Caledonia**	**Chittenden**	**Essex**	**Franklin**	**Grand Isle**	**Lamoille**	**Orange**	**Orleans**	**Rutland**	**Washington**	**Windham**	**Windsor**
Energy Goods	**-172.32**	**-172.65**	**-176.51**	**-123.45**	**-179.06**	**-170.57**	**-190.87**	**-159.83**	**-166.12**	**-167.06**	**-171.64**	**-164.40**	**-159.34**	**-168.71**
Electricity	0.64	0.62	0.54	0.53	0.47	0.63	0.51	0.54	0.53	0.46	0.59	0.55	0.57	0.60
Fuel Oil and Other Fuels	-86.46	-92.27	-88.72	-36.03	-86.48	-74.41	-89.79	-75.31	-77.18	-83.05	-90.65	-83.03	-76.68	-80.91
Motor Vehicle Fuels (and lubricants and fluids)	-86.01	-80.40	-88.02	-71.46	-92.86	-89.42	-100.85	-84.63	-89.00	-84.30	-81.21	-81.33	-82.90	-87.76
Natural Gas	-0.48	-0.60	-0.31	-16.50	-0.19	-7.37	-0.74	-0.43	-0.48	-0.18	-0.38	-0.59	-0.34	-0.64
Other Goods	**-162.99**	**-153.32**	**-145.84**	**-173.31**	**-131.83**	**-161.80**	**-166.24**	**-155.41**	**-156.03**	**-141.09**	**-149.16**	**-161.26**	**-150.16**	**-158.90**
Sources of Income	**283.50**	**282.39**	**278.67**	**284.80**	**273.99**	**282.54**	**287.79**	**281.17**	**280.63**	**276.79**	**279.58**	**282.39**	**280.48**	**283.54**
Capital	20.94	18.18	14.70	26.12	10.61	20.39	23.77	18.47	17.75	13.41	16.10	20.52	16.54	20.50
Labor	103.37	94.85	81.41	118.38	65.20	100.79	115.83	94.17	91.67	75.79	86.12	100.96	88.33	102.25
Other Sources	159.20	169.36	182.56	140.31	198.18	161.36	148.19	168.52	171.21	187.59	177.35	160.91	175.61	160.79
Total	**-51.80**	**-43.58**	**-43.67**	**-11.96**	**-36.90**	**-49.84**	**-69.32**	**-34.07**	**-41.53**	**-31.36**	**-41.22**	**-43.26**	**-29.02**	**-44.08**

Note: Carbon pricing design: transportation and heating sector, WCI price path, lump-sum rebates, Vermont only.

Table 4.24(f). Changes in Economic Welfare by County (Average Household) under Transportation-only Coverage, 2020

Economic Welfare Change by County (2015$ per household)	Addison	Bennington	Caledonia	Chittenden	Essex	Franklin	Grand Isle	Lamoille	Orange	Orleans	Rutland	Washington	Windham	Windsor
Energy Goods	**-87.33**	**-81.76**	**-89.22**	**-73.11**	**-93.92**	**-90.98**	**-101.99**	**-85.74**	**-90.10**	**-85.35**	**-82.51**	**-82.52**	**-84.06**	**-89.00**
Electricity	-0.86	-0.84	-0.74	-0.73	-0.64	-0.85	-0.69	-0.74	-0.72	-0.63	-0.81	-0.75	-0.77	-0.81
Fuel Oil and Other Fuels	-0.66	-0.71	-0.68	-0.28	-0.66	-0.57	-0.69	-0.58	-0.59	-0.64	-0.69	-0.64	-0.59	-0.62
Motor Vehicle Fuels (and lubricants and fluids)	-85.78	-80.18	-87.79	-71.27	-92.61	-89.18	-100.58	-84.41	-88.76	-84.08	-80.99	-81.11	-82.68	-87.53
Natural Gas	-0.02	-0.03	-0.02	-0.84	-0.01	-0.37	-0.04	-0.02	-0.02	-0.01	-0.02	-0.03	-0.02	-0.03
Other Goods	**-78.21**	**-73.57**	**-69.98**	**-83.17**	**-63.26**	**-77.64**	**-79.77**	**-74.58**	**-74.87**	**-67.70**	**-71.58**	**-77.38**	**-72.06**	**-76.25**
Sources of Income	**141.90**	**141.22**	**139.28**	**142.81**	**136.84**	**141.42**	**144.08**	**140.66**	**140.37**	**138.32**	**139.78**	**141.36**	**140.23**	**141.89**
Capital	16.39	14.23	11.51	20.44	8.31	15.96	18.60	14.46	13.90	10.49	12.60	16.06	12.95	16.04
Labor	49.72	45.63	39.16	56.94	31.36	48.48	55.72	45.30	44.09	36.46	41.43	48.56	42.49	49.18
Other Sources	75.79	81.36	88.61	65.43	97.18	76.98	69.75	80.91	82.38	91.37	85.75	76.73	84.79	76.67
Total	**-23.64**	**-14.11**	**-19.93**	**-13.46**	**-20.34**	**-27.20**	**-37.69**	**-19.65**	**-24.60**	**-14.73**	**-14.31**	**-18.55**	**-15.88**	**-23.36**

Note: Carbon pricing design: transportation sector, WCI price path, lump-sum rebates, Vermont only.

4.6. Regional Coverage

Our analysis has focused thus far on the impacts of carbon pricing policies that apply to Vermont only.[68] Alternatively, Vermont could join a coalition of other New England states to jointly pursue a common carbon pricing policy. States could implement a common carbon tax or join the Western Climate Initiative as a group. In December 2018, Vermont joined a coalition of 8 other Northeast and Mid-Atlantic states (and the District of Columbia) to announce the intention of designing a new transportation policy proposal "to cap and reduce emissions from the combustion of transportation fuels".[69] While the design details are still unknown, such a policy could look similar to expanding the RGGI cap-and-trade program to include the transportation sector.

The benefits of joint action are obvious. Small New England states with integrated economies would benefit from increasing returns to scale with a common policy, and border issues related to trade and competitiveness issues would be mitigated. Businesses would have less incentive to move across borders, and drivers would have less incentive to fill their gas in neighboring states without a carbon pricing policy.

To assess the impacts of a New England carbon pricing policy, we ran a set of simulations in which the entire New England census division (Vermont, New Hampshire, Maine, Massachusetts, Rhode Island, and Connecticut) implements the same carbon pricing policy, and we compared the results with those of an otherwise identical policy that covers Vermont emissions only. Perhaps surprisingly, we find that the economic and emissions impacts in Vermont depend almost entirely on the carbon price in Vermont; there is little difference in impacts between Vermont-only and New England policies. In the case of Vermont, we find that the benefits of coordination are offset by trade effects. Carbon prices in neighboring states increase the costs of importing goods produced in neighboring states, and a small reduction in income in neighboring states slightly reduces exports of Vermont-produced goods to those states. Overall, we find that adding neighboring states to a carbon pricing policy results in very slight increases in the change to both state GDP and economic welfare of the policy options considered. At the same time, we find that overall emissions reductions are much larger simply because of the larger scale of emissions coverage, and the overall climate benefits to Vermont (and the rest of the world) increase by an order of magnitude.

Importantly, our analysis of a Vermont or New England carbon price holds the price of emissions fixed. Under carbon tax policies, this assumption simply means that the choice of a carbon tax rate will be the same for a New England policy as a Vermont-only policy. Under cap-and-trade programs such as the WCI, however, it becomes much less clear whether the allowance price would remain the same if Vermont were joined by a group of New England states. The impact on allowance prices would depend on the specific details of the program; without knowing those details, we are unable to project how allowance prices would vary between Vermont-only and New England cap-and-trade programs.

4.7. Carbon Price Policy Case Studies

The analysis thus far of carbon pricing policy options using the RFF-DR CGE and RFF incidence models has used illustrative examples to demonstrate how the impacts of carbon pricing in Vermont vary with the level of the carbon price, the use of revenue, the scope of coverage within Vermont, and the regional scope of the policy. This section provides an analysis of three specific policy options for the state of Vermont, with a focus on impacts in 2025 and 2030. The first policy considered is the carbon tax policy proposed in the ESSEX Plan (H.791). The second and third policies are cap-and-trade program options. In the second policy, Vermont joins the Western Climate Initiative. In the third policy option, Vermont joins a regional collaboration of Northeast and Mid-Atlantic states to cap emissions from transportation fuels through the Transportation and Climate Initiative.

ESSEX Plan

Background

The ESSEX plan (an Economy Strengthening Strategic Energy eXchange) will, according to its authors, 1) "provide Vermonters the cleanest electricity at the lowest rates in New England", 2) "prioritize working families and rural Vermonters in the transition to the lower-cost/lower-carbon energy future" and 3) "harness the power of the market to reduce carbon pollution and help the state meet its climate and clean energy goals". Source: Curran et al. (2017).

The plan features a gradually rising fee on carbon dioxide emissions, starting at $5 and rising $5 per year until the price hits $40 per ton (it's not clear if the price is linked to inflation or not). Revenues from fees derived from commercial and industrial emissions will be rebated to firms through electricity subsidies. The revenues from the residential and transportation sectors will be rebated to households through electricity subsidies and targeted rebates to low and moderate income or rural Vermonters.

Impacts in 2025

GHG Emissions Level: 8.8 MMTCO2e (14 percent below 2005)
Percentage Change in state GDP: +0.05 percent
Percentage Change in Aggregate Labor Demand: +0.05 percent
Change in Aggregate Economic Welfare: –$18.1 million (2015$)
Environmental Benefits: +$33.8 million (2015$)

ESSEX Plan (continued)

Impacts in 2030

GHG Emissions Level: 8.2 MMTCO2e (20 percent below 2005)
Percentage Change in state GDP: +0.06 percent
Percentage Change in Aggregate Labor Demand: +0.06 percent
Change in Aggregate Economic Welfare: –$42.2 million (2015$)
Environmental Benefits: +$57.5 million (2015$)

Changes in Economic Welfare by Household Groups (2020)

Economic Welfare Change by Quintile and County (Average Household) (2015$ per household)

Q1	Q2	Q3	Q4	Q5		Urban*	Rural
+$37	+$24	+$5	-$46	-$51		+$0	-$8

* Chittenden County

Western Climate Initiative

Background

The Western Climate Initiative (WCI) is a North American cap-and-trade program that includes California and the province of Quebec. This program is economy-wide and covers about 85 percent of emissions, including emissions associated with electricity, industry, transportation, and home heating. This program has a minimum auction price similar in design to RGGI. The California price is set at $14.53 in 2018 and rises at 5 percent per year plus inflation. Quebec has a lower minimum auction price of $14.35 (Can$) that rises at the same rate. The auction prices in the WCI have hovered just above the California price floor for several auctions. California constitutes over 75 percent of the emissions in the WCI. Linking to the WCI would be conceivable for Vermont; for example, one pathway might be to link sectors other than electricity to the WCI.

For this analysis, we assume that Vermont links its transportation and heating sectors to the WCI. We further assume that the allowance price would continue to follow the minimum auction price. First, Vermont's emissions are small relative to California's; it would be unlikely that Vermont could significantly shift demand for allowances. Second, we anticipate that California's Air Resource Board (CARB) would continue to pursue complementary policies, such as the new home solar mandate, that would place downward pressure on the allowance price. And without knowing how Vermont would spend the WCI auction revenue, we simply assume the revenue is returned via lump-sum rebates. Note that this assumption is especially important to the low-income and rural households; these households benefit substantially more from lump-sum rebates than from other revenue uses, and would experience much different welfare impacts if revenues were used in a different manner.

Impacts in 2025

GHG Emissions Level: 8.8 MMTCO2e (14 percent below 2005)
Percentage Change in state GDP: –0.02 percent
Percentage Change in Aggregate Labor Demand: –0.02 percent
Change in Aggregate Economic Welfare: –$12.1 million (2015$)
Environmental Benefits: +$20.0 million (2015$)

Western Climate Initiative (continued)

Impacts in 2030

GHG Emissions Level: 8.4 MMTCO2e (18 percent below 2005)
Percentage Change in state GDP: –0.02 percent
Percentage Change in Aggregate Labor Demand: –0.02 percent
Change in Aggregate Economic Welfare: –$14.7 million (2015$)
Environmental Benefits: +$25.5 million (2015$)

Changes in Economic Welfare by Household Groups (2020)

Economic Welfare Change by Quintile and County (Average Household) (2015$ per household)

Q1	Q2	Q3	Q4	Q5	Urban*	Rural
+$96	$+35	–$38	–$15	–$251	–$12	–$42

* Chittenden County

Transportation and Climate Initiative

Background

In December 2018, 9 Northeast and Mid-Atlantic states (and the District of Columbia) announced they would design a policy proposal to cap carbon dioxide emissions from the transportation sector through the Transportation and Climate Initiative (TCI). Peter Walke, Deputy Secretary of the Vermont Agency of Natural Resources, has said, “Addressing greenhouse gas emissions from the transportation sector requires working together across state lines... Vermont is pleased to take this next step and begin working with our partner states to develop a specific policy proposal to address transportation emissions.”*

One potential policy outcome is a cap-and-trade program that covers transportation fuels that is similar to the RGGI cap-and-trade program. However, the policy proposal will require detailed negotiations with the other participating states and, as a result, the TCI scenario analyzed here is purely speculative. For simplicity, we assume that the cap is set such that the allowance price follows the WCI price path scenario used throughout this analysis (any allowance price path lower than the WCI price path would have very small effects on Vermont’s transportation emissions). We also assume, again for simplicity, that Vermont’s share of the auction revenue is returned to households via lump-sum rebates. However, we again note that the changes in welfare to low-income and rural households would be much different under alternative assumptions about how the revenue is spent by Vermont.

Impacts in 2025

GHG Emissions Level: 8.9 MMTCO2e (13 percent below 2005)
Percentage Change in state GDP: –0.01 percent
Percentage Change in Aggregate Labor Demand: –0.01 percent
Change in Aggregate Economic Welfare: –$7.1 million (2015$)
Aggregate Welfare Benefits: $14.2 million (2015$)

Impacts in 2030

GHG Emissions Level: 8.5 MMTCO2e (17 percent below 2005)
Percentage Change in state GDP: –0.01 percent
Percentage Change in Aggregate Labor Demand: –0.01 percent
Change in Aggregate Economic Welfare: –$8.6 million (2015$)
Environmental Benefits: +$17.8 million (2015$)

Transportation and Climate Initiative (continued)

Changes in Economic Welfare by Household Groups (2020)

Economic Welfare Change by Quintile and County (Average Household) (2015$ per household)

Q1	Q2	Q3	Q4	Q5	Urban**	Rural
+$53	$+18	–$18	–$22	–$122	–$13	–$20

** Chittenden County

* https://www.transportationandclimate.org.

4.8. Combining Carbon Pricing and Nonpricing Approaches

Our analysis above has indicated that Vermont is unlikely to meet its 2025 or 2030 GHG emissions targets if it pursues a carbon pricing-only policy approach. To meet its emissions targets, however, Vermont could pursue a policy strategy that incorporates both carbon pricing and nonpricing approaches. The two options are not mutually exclusive. Further, carbon pricing policies could provide the revenue necessary to successfully finance and implement nonpricing policies. Thus, Vermont could dedicate a portion of its carbon revenues to government investment in these nonpricing policies and return the remainder of the revenue to households or firms via lump-sum rebates, reductions in other taxes, or electricity subsidies. A policy that invests a portion of carbon pricing revenue to further reduce emissions would be similar to the RGGI program (Vermont has chosen to invest nearly all of its RGGI revenue in energy efficiency).

Vermont policymakers should keep in mind the distributional equity consequences of various revenue recycling decisions (as discussed above), and that the distributional effects of nonpricing decarbonization policies (e.g. energy efficiency retrofits, EV charging station investments, etc.) are not well understood, calling for further research and analysis. However, it is likely possible to dedicate some revenues to keeping low-income households "whole" (with direct rebates or tax cuts), while still dedicating significant revenue to nonpricing decarbonization policies.

As mentioned previously, we are unable to provide an integrated modeling analysis of the economic and environmental impacts of a carbon pricing and nonpricing combined approach. However, to provide a rough estimate of the types of emissions reductions that could be achieved, we provide here a rough, back-of-the-envelope calculation, by simply adding reductions from pricing and nonpricing policies, an assumption that is probably overly optimistic.[70] For 2025, we assume nonpricing policies achieve 1.9 $MMTCO_2e$ additional reductions;[71] for 2030, we estimate total nonpricing emissions reductions to be 2.7 $MMTCO_2e$.[72] We cannot provide any cost estimates for these combined policies, but one would expect the combined policy to be more expensive than achieving the same total emissions reduction via carbon pricing alone, because of the general cost-effectiveness advantage of pricing over non-pricing policies (discussed in section 4.1.1 of this report).

Table 4.25 reports the combined pricing and nonpricing emissions by sector under the four alternative price path scenarios, assuming lump-sum rebates, economy-wide (electricity exempt) coverage, and that Vermont implements the given carbon pricing policies alone ("Vermont-only"). By combining carbon pricing with nonpricing policies, this back-of-the-envelope calculation suggests that Vermont emissions in 2025 will be 33–38 percent below 2005 levels. This means that under all four price path scenarios Vermont would meet the US Climate Alliance targets (26–28 percent reduction from 2005 levels by 2025). Further, in 2030, these projections suggest that Vermont could reduce emissions by 44-51 percent of 2005 levels, or 34-41 percent of 1990 levels—achieving the midrange of the NEG/ECP goals (35–45 percent reductions below 1990 levels), especially if Vermont pursues the most stringent ("high") pricing scenario considered in this analysis.

Table 4.26 reports the emissions by sector under three alternative sectoral coverage scenarios, assuming the WCI price path, lump-sum rebates, and Vermont-only. Because of the size of nonpricing policy emissions reductions estimates, the combined policy requires little additional reductions from carbon pricing to achieve the 2025 US Climate Alliance targets; even the transportation only coverage with the WCI price path meets these goals. However, because the assumed price path is relatively low, none of these options can meet the various longer-term targets.

Table 4.25. VT GHG Emissions by Sector by Carbon Price Path, Pricing and Nonpricing Policies

Million Metric Tons CO_2 Equivalent ($MMTCO_2e$)											
	2015	2025					2030				
	Historical		Carbon Price Path					Carbon Price Path			
Sector		BAU + Non-pricing	ESSEX	WCI	Medium	High	BAU + Non-pricing	ESSEX	WCI	Medium	High
Electricity (consumption based)	1.0	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Residential/ Commercial/ Industrial Fuel Use	2.8	1.7	1.5	1.6	1.5	1.4	1.2	1.0	1.1	1.0	0.8
Transportation	4.3	3.4	3.2	3.2	3.1	2.9	3.0	2.7	2.8	2.6	2.4
Fossil Fuel Industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial Processes	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Waste Management	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Agriculture	1.1	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8
Total	**10.0**	**7.2**	**6.8**	**6.9**	**6.7**	**6.3**	**6.0**	**5.5**	**5.7**	**5.4**	**5.0**
Total Relative to 1990	16%	-16%	-21%	-20%	-22%	-26%	-31%	-36%	-34%	-37%	-41%
Total Relative to 2005	-2%	-30%	-34%	-33%	-35%	-38%	-42%	-46%	-44%	-47%	-51%

Note: Carbon pricing design: lump-sum rebates, economy-wide (electricity exempt), Vermont only.

Table 4.26. VT GHG Emissions by Sector by Sectoral Coverage, Pricing and Non-Pricing Policies

Million Metric Tons CO_2 Equivalent ($MMTCO_2e$)									
	2015	2025				2030			
	Historical		Carbon Price Path				Carbon Price Path		
Sector		BAU + Non-pricing	Economy-Wide (electricity exempt)	Transport and Heating Fuels	Transport only	BAU + Non-pricing	Economy-Wide (electricity exempt)	Transport and Heating Fuels	Transport only
Electricity (consumption based)	1.0	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
Residential/ Commercial/ Industrial Fuel Use	2.8	1.7	1.6	1.6	1.7	1.2	1.1	1.1	1.2
Transportation	4.3	3.4	3.2	3.2	3.2	3.0	2.8	2.8	2.8
Fossil Fuel Industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial Processes	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Waste Management	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Agriculture	1.1	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8
Total	**10.0**	**7.2**	**6.9**	**6.9**	**7.0**	**6.0**	**5.7**	**5.7**	**5.8**
Total Relative to 1990	16%	-16%	-20%	-20%	-19%	-31%	-34%	-34%	-32%
Total Relative to 2005	-2%	-30%	-33%	-32%	-32%	-42%	-44%	-44%	-43%

Note: Carbon pricing design: WCI price path, lump-sum rebates, Vermont only.

5. Other Observations

There are a number of relevant considerations to decarbonization policies in Vermont that are beyond the scope of our quantitative analysis, including (a) the extent to which Vermont decarbonization policy would induce technological innovation, (b) detailed policy analysis of nonpricing policy options, and (c) the impact of Vermont decarbonization on global climate. We briefly address each of these three topics below.

5.1. Innovation

Sec. C.110.(b)(3)(a) of Act 11, which authorized this analysis, specifically asked for "the comparative ability or potential of the policies … to encourage innovation in the State." The RFF-DR CGE model cannot measure the impact of policy-induced innovations (or, in other words, changes in sector-specific productivity caused by policy-driven changes in demand). For example, a policy that encourages drivers to purchase EVs could create an incentive for automakers to improve the efficiency of producing EVs and ultimately lower the costs of EVs to future buyers. Because the model does not estimate such productivity improvements, our analysis would underestimate emissions reductions if this type of innovation were to occur.

To answer the question of whether Vermont's decarbonization policies can encourage innovation, one must consider three interrelated questions: (1) Is there a pathway to innovation? (2) Which type of innovation would apply: hard innovation, increases in the productivity of the production of physical products such as solar panels or wind turbines, or soft innovation, increases in the productivity of installation of physical products? (3) Are the financial benefits of innovation captured by local (Vermont, in this case) firms or workers?

In the case of Vermont decarbonization policies, it is hard to imagine that a market as small as Vermont's would induce innovation in global technology markets such as electric vehicles and heat pumps. If any innovation were to occur, it would most likely be soft innovation. One could easily imagine that Vermont firms and workers could become more efficient at installing clean energy technologies for other firms and households as the demand for such technology increases. The benefits of this type of innovation would be retained by Vermont, as installation is a local activity. If this type of innovation were to occur, then we would expect greater emissions reductions and lower welfare costs than the results from the RFF-DR CGE model. Unfortunately, we are unable to quantify the scale of this type of innovation due to Vermont decarbonization policies and therefore cannot quantitatively estimate these gains.

5.2. Policy Analysis of Nonpricing Options

As discussed above, our nonpricing analysis relies on the emissions reduction estimates from the Vermont Climate Action Commission (VCAC) and our own back-of-the-envelope estimate of emissions reductions associated with increases in the stringency of the Vermont RES. These estimates are based on detailed goals (for example, the number of space and water heat pumps by 2025) and the assumption that these goals will be attained. There is little analysis, however, of the types of policies the state can implement to actually achieve these goals. If the state of Vermont chooses to rely in full or in part on emissions reductions from the nonpricing policies recommended by the VCAC, future analysis will be needed to identify how to map goals into policies and what the cost of those policies will be to the state.

5.3. Vermont and the Global Climate

Our modeling analysis does not convert changes in Vermont's emissions into changes in predicted global average temperatures. But needless to say, the impact of Vermont's policies on global temperature will be small. Vermont is a small state in a large country in an even bigger world. The damages of carbon dioxide and other greenhouse gas emissions, as global pollutants, are independent of the geographic source of those emissions. Therefore, the success of Vermont's decarbonization strategy will depend on the extent to which it drives action in other states or other countries. Vermont cannot solve the climate challenge on its own, but if Vermont's policy leadership were to inspire increased leadership and policy innovation in other states or nations—it would indeed amount to a significant impact.

6. Conclusions

This study, requested by the Vermont legislature through Act 11 in June 2018, provides objective information on methods to reduce greenhouse gas (GHG) emissions in Vermont. The state of Vermont's GHG emissions have been increasing since 2011, and the state is not currently on a pathway to meeting its various emissions targets. Vermonters have made progress implementing policies to reduce GHG emissions, such as the Regional Greenhouse Gas Initiative (RGGI), Efficiency Vermont, zero emissions vehicle (ZEV) standards and more. However, in the absence of federal leadership, additional state policy will likely be required to meet the state's emissions targets.

This report discusses two classes of policies that Vermont can pursue to further advance decarbonization in the state: (a) carbon pricing policies, such as carbon taxes or cap-and-trade programs, and (b) nonpricing policies, such as financial incentives, mandates, or direct investments.

A thorough quantitative analysis of nonpricing policies is beyond the scope of this project, but we do show that Vermont could reduce emissions in the range of 0.8–3.0 $MMTCO_2e$ by 2025 if it pursued the comprehensive set of recommendations in the VCAC report (over 30 distinct actions) and increased the state's Renewable Energy Standard (RES) to 100 percent by 2030.[73] The state could meet its 2025 US Climate Alliance emissions target (26–28 percent reduction below 2005 levels by 2025) with this collection of nonpricing policies, however only under the most optimistic assumptions. We see no path by which the state could meet its 2028 statutory target (50 percent below 1990 levels) with a decarbonization strategy that includes only these nonpricing policies.

Our detailed evaluation of a broad set of carbon pricing policies suggests that a carbon pricing-only decarbonization strategy in Vermont is also unlikely to produce the level of GHG reductions required to meet the state's climate targets (unless the carbon price is set substantially higher than levels considered in this study). Economically, carbon pricing policy approaches generally produce gross costs ($20-$100 per person annually) but net benefits: the monetary benefits of reduced carbon dioxide emissions and cleaner local air exceed the economic costs of all carbon policy approaches analyzed in this study.

A combined carbon pricing and nonpricing approach in which the carbon revenues are used to finance the nonpricing approaches could deliver much larger emissions reductions than a carbon pricing-only approach – indeed, our analysis suggests that such a combined approach could achieve reductions consistent with the 2025 US Climate Alliance targets with moderate carbon prices and only the median estimate of emissions reductions from the nonpricing policies. However, to the extent that the carbon revenues are used to directly finance these policies, the combined approach would forgo the benefits of returning revenues directly to households. A carbon pricing-only approach with lump-sum rebates, on the other hand, would deliver less emissions reductions but provide direct positive economic benefits to low-income households; a carbon pricing-only strategy with reductions in taxes on wage income, on the other hand, may be beneficial to Vermont's economy but harm Vermont's low-income households. If policymakers choose carbon pricing as part of their decarbonization strategy, they must balance a trade-off among efficiency, equity, and the environment when they decide how to utilize the carbon revenues.

Appendix A: Evaluating Electric Vehicle Purchase Incentives

To provide an example of the sort of additional policy analysis that may be valuable for Vermont to consider in its evaluation of nonpricing policies, we look at the extent to which a government incentive program would induce drivers to purchase more electric vehicles.

A.1. Background

As recommended in the VCAC report, Vermont could subsidize plug-in vehicles using carbon price revenue or other sources of revenue, such as funds from the VW settlement agreement.[74] We discuss the effects on vehicle sales and emissions of subsidizing purchases or leases of plug-ins.

Vermont has a distinctive market for passenger vehicles. Typically, about 40,000 new vehicles are sold each year in the state. About two-thirds of those vehicles are light trucks, which is similar to the national average. As in much of the country, the share of light trucks in total new vehicle sales has been increasing over the past few years. Compared with national averages, GMC, Subaru, and Toyota vehicles tend to sell well in Vermont, whereas Honda, Hyundai, and Nissan tend to sell relatively poorly.

The market penetration of plug-ins in Vermont is comparable to that of other states in the Northeast and the United States more generally. In Vermont, plug-ins account for less than 1 percent of all new vehicle sales, most of which are plug-in hybrids rather than all-electrics. For example, plug-in sales in 2015 were about 400 units. With the exception of the Toyota RAV4, all plug-in vehicles sold in the US market are cars. It appears that to date, all plug-ins sold in Vermont are passenger cars, with the Toyota Prius and Ford C-Max among the most popular plug-in hybrids and the Nissan Leaf the most popular all-electric. Plug-ins account for less than 1 percent of all registered vehicles in Vermont.

As of 2015, Vermont had about 150 public charging stations, which is more than New Hampshire and Maine and fewer than Massachusetts. Many of these stations offer free charging, and they tend to be concentrated in densely populated areas. Most of these stations are Level 2, meaning that it is possible to charge about 10 miles of range per hour; a Leaf with an empty battery would take about eight hours to charge fully. However, any particular vehicle cannot use all available charging stations. There are three charging standards, and each vehicle can use only those stations that have the appropriate standard. For example, Tesla has its own standard, and only Teslas can use those stations.

A.2. Policies

Vermont belongs to the set of states that have joined California's Zero Emission Vehicle (ZEV) program. The program sets annual targets for ZEV sales for most vehicle manufacturers and provides credits for both all-electric and plug-in hybrid vehicles. Because Vermont participates in this program, the plug-ins sold in Vermont are counted toward the total sales target. The sales target for California and other states is about 80,000 in 2018 and grows to about 300,000 in 2025.[75]

Vermont does not offer statewide vehicle subsidies, but its renewable energy standard incentivizes utilities to promote plug-in vehicles. As a result, many utilities subsidize plug-ins. A prominent example is Green Mountain Power, which has offered rebates for the Leaf of $5,000 to $10,000 at various times in recent years; other utilities typically offer smaller subsidies, some of which are targeted at low-income households. A Level 2 home charging station may cost roughly $2,000, and some utilities offer subsidies for home charging systems. For example, Green Mountain Power offers free Level 2 charging equipment with the purchase of an electric vehicle and subsidizes the charging equipment for existing electric vehicles.

A.3. Modeling the Effects of Subsidies on Vehicle Sales

The subsidy could go to purchasers in the form of a rebate or tax credit or could go to dealers. A tax credit could have a different effect than a subsidy if consumers are uncertain about whether they will have sufficient tax liability to be able to claim the entire credit or for other reasons. We model a purchase rebate for simplicity.

We consider rebates of $1,000, $3,000, and $5,000 that are offered in addition to the federal tax credit of up to $7,500. For comparison, New York offers a subsidy of $2,000 per vehicle.

We use an RFF vehicle choice model to simulate the rebate. In the model, each household chooses a vehicle based on vehicle price, fuel economy, performance, size, and a composite of all other attributes (for example, cargo space or exterior styling). Vehicles are defined in a highly disaggregated manner, distinguishing among different trims of a model and different fuel types (for example, the Prius V from the Prius plug-in); there are about 1,200 unique vehicles in the data. The model includes a unique set of preference parameters for each of 20 demographic groups based on income (5 groups), urban/rural, and age (2 groups). Parameters are estimated using proprietary survey data on recent vehicle buyers, which includes about 1 million vehicle buyers (or about 1 percent of all vehicle buyers in the United States) from 2010 through 2015.

In the simulation, the rebate reduces the price that the consumer pays. The lower price increases demand for the vehicle, and we use the model to simulate the increase in plug-in sales. The model also predicts the decrease in sales of other vehicles. We expect sales to decrease more for vehicles that are similar to plug-ins in terms of fuel costs, market segment, or other factors.

The effect of the rebate on sales depends on the extent to which the rebate reduces the net price that consumers pay. The fact that the rebate is offered to the consumer does not imply that the consumer captures the full value of the rebate. For example, suppose a plug-in would have sold for $40,000 without the rebate. If the price with the rebate remains at $40,000, the consumer would capture the full value because the postrebate price would be $39,000. But the dealer will realize that raising the price above $40,000 allows the dealer to capture some of the value of the rebate. In other words, the dealer faces a trade-off. On the one hand, reducing the postrebate price to $39,000 boosts sales compared with the situation without a rebate. On the other hand, raising the postrebate price above $39,000 allows the dealer to make more profit for each vehicle that is sold. The dealer balances these trade-offs between higher sales and higher profits per vehicle. Economic theory and available evidence for other policies suggest that the postrebate price should not fall by the full value of the rebate, meaning that the dealer captures some of the rebate. This situation represents the distinction that economists make between statutory incidence (who can claim the rebate) and economic incidence (who actually benefits from the rebate).

Before presenting the results, we provide a rough estimate of the effects of the rebate with some simple calculations. The average sales price of a plug-in vehicle in the data is about $40,000. If consumers capture the full $1,000 subsidy, the price would fall by 2.5 percent. The own-price elasticity of demand is a measure of the sensitivity of demand to the price of the vehicle. An elasticity of –4 means that a 1 percent decrease in price raises sales by 4 percent. In our model, the average own-price elasticity of demand for all vehicles is about –4.

The elasticity is this large in magnitude because the vehicles are defined at such a disaggregated level. In the model, consumers can choose among vehicles that are very similar to one another, such as different drive types or trims of the same model. Consequently, a small change in the price of one vehicle can cause a relatively large change in the sales of that vehicle, as consumers substitute across closely related vehicles.

The elasticity varies across vehicles, and for plug-ins the average is about –2.5. This number is lower than the overall average primarily because high-income consumers tend to be less sensitive to prices than low-income consumers, and high-income consumers account for most plug-in vehicle purchases. Therefore, if consumers capture the full $1,000, plug-in sales would increase by 7 percent. Because of the incidence argument above, we expect the $1,000 subsidy to increase demand by less than 7 percent.

Table A.1 displays the simulation results. The first column shows the baseline scenario, which does not include subsidies to plug-ins and does include the federal tax credit. The remaining columns show scenarios that include the plug-in subsidy indicated in the column heading. Each of the rows display the outcome indicated in the row heading. All simulations are based on data from the year 2015 and reflect vehicle choices that were available to consumers at the time.

Table A.1. Effects of Plug-In Vehicle Subsidies

	(1)	(2)	(3)	(4)
	Subsidy amount (2015$ per vehicle)			
	0	1,000	3,000	5,000
Plug-in sales (units)	223	241	308	396
Subsidy expenditure (million 2015$)		0.24	0.92	1.98
Average postsubsidy vehicle price (2015$)	56,238	54,649	50,510	46,446
Consumer share of subsidy		0.80	0.99	1.02
Average fuel economy of non-plug-ins (miles per gallon)	24.23	24.20	24.20	24.20
Lifetime emissions change (tons carbon dioxide)		1,137	3,908	7,519
Subsidy expenditure per emissions change ($ per ton)		212	237	263

Notes: Each column reports results from a separate simulation. Column 1 is the baseline, which includes no subsidies for plug-in vehicles. Columns 2 through 4 include the plug-in subsidy amounts indicated in the column headings. The row plug-in sales reports the total number of plug-ins sold in each scenario. The subsidy expenditure equals the number of sales multiplied by the subsidy amount. The average postsubsidy vehicle price is the sales-weighted average plug-in sales price, after including the subsidy. The consumer share of subsidy is the sales-weighted ratio of the change in price the consumer pays between the subsidy and no-subsidy scenarios, and the subsidy amount. The average fuel economy of non-plug-ins is the sales-weighted average fuel economy, in miles per gallon. Lifetime emissions change is the difference between the lifetime emissions of vehicles sold in column 1 and lifetime emissions of vehicles sold in the corresponding scenario. Subsidy expenditure per emissions change is the ratio of the two numbers reported in the table. See text for details on assumptions.

The model predicts sales of 223 plug-ins in the absence of any subsidies, implying a market share of about 0.5 percent, which is similar to the actual market shares in the mid-2010s. The average purchase price was about $56,000 (all dollar numbers are in 2015$).

Column 2 shows that offering a subsidy of $1,000 per vehicle increases sales by about 10 percent. The subsidy expenditure equals $1,000 per vehicle multiplied by the number of plug-ins sold, or about $240,000. The average postsubsidy price is about $1,600 lower with the $1,000 subsidy than without it. The figure of $1,600 reflects two effects. First, consumers capture about 80 percent of the $1,000 subsidy, meaning that the postsubsidy price declines by 80 percent of the subsidy amount, or by $800. Second, the subsidy causes a disproportionate increase in lower-priced plug-ins than in higher-priced plug-ins, which reduces the sales-weighted average price. These two factors contribute roughly equally to the combined $1,600 decrease in average purchase price.

The model also predicts which vehicles consumers substitute from because of the subsidy. According to the model, vehicles with high fuel economy tend to be closer substitutes for plug-ins than vehicles with lower fuel economy, because of which the model predicts a disproportionate shift from high fuel economy vehicles to plug-ins. This effect slightly reduces the sales-weighted average fuel economy of non-plug-ins. See Table 3.3 for estimates of this effect.

We use the simulation results to compute the effect of the subsidy on CO_2 emissions from vehicles sold in 2015. By increasing plug-in sales in 2015, the subsidy reduces emissions in subsequent years. The change in emissions in any year depends on how much the plug-ins and other vehicles are driven and on scrappage decisions.

Because our model does not incorporate these decisions, we take a similar approach to that taken by the US Environmental Protection Agency and the National Highway Traffic Safety Administration in evaluating vehicle fuel economy and greenhouse gas standards. Specifically, we assume that each vehicle sold in 2015 is driven a certain number of miles over its lifetime. We calculate the lifetime emissions of each of the 40,000 vehicles sold in 2015, with and without the subsidy, and report the change in emissions caused by the subsidy. Conceptually, this change includes the fact that plug-ins have lower lifetime emissions and the slightly lower average fuel economy of non-plug-ins with the subsidy.[76]

The subsidy of $1,000 per vehicle reduces future CO_2 emissions by about 1,000 metric tons. Given the subsidy expenditure of $240,000, we compute a subsidy cost of about $200 per metric ton of CO2.

The remaining columns show the results for subsidies of $3,000 and $5,000 per vehicle. The results scale more than proportionately to the size of the subsidy, so that the $5,000 subsidy raises plug-in sales by more than five times the amount by which the $1,000 increases sales. The nonlinearity arises from the fact that the lower levels of the subsidy encourage consumers who value plug-ins and non-plug-ins similarly to one another. These consumers account for a small share of the market, and higher subsidies make plug-ins attractive to more mainstream consumers. However, we caution about extrapolating the results much further, given the price and market share variation observed in the data used to estimate the parameters in the vehicle choice model.

A.4. Discussion

Several caveats pertain to the estimated effects of the subsidies. First, the vehicle choice model is nationally representative. As discussed, Vermont's passenger vehicle market is similar to the national market in some ways, such as in the mix of cars and trucks and the market share of plug-ins. But in other ways, Vermont is unusual, such as in the share of rural households and the high market share of vehicles with all-wheel drive. Because few plug-in vehicles currently on the market have all-wheel drive, plug-in subsidies may be less effective in Vermont than nationally. That preference may explain why the sales changes caused by the $5,000 subsidy are larger than the increase in Nissan Leaf sales that occurred when Green Mountain Power offered a $10,000 subsidy. [77] For that reason, the estimates reported here may represent an upper bound on the effect of a subsidy in Vermont.

Unfortunately, we do not have sufficiently detailed vehicle sales data to estimate a vehicle choice model specific to Vermont, but we can account for differences in demographics between Vermont and the United States as a whole. It turns out that accounting for demographics has a small effect on the estimates reported in the table.

The second caveat is that the vehicle choice model does not include public charging station availability. Instead, the model incorporates a composite vehicle attribute, which includes anything about the vehicle other than price, fuel costs, performance, and size—that is, it includes charging station availability. Because the preference parameters are estimated using data from 2010 through 2015, the simulation results can be interpreted as characterizing the effects of the subsidies given the level of charging station availability during the years 2010 through 2015.

The third caveat is that the vehicle choice model is not dynamic, so predicted sales in a particular time period do not depend on previous sales. One argument for subsidizing plug-in vehicles is that raising sales in one period increases consumer awareness and information about plug-in vehicles, potentially raising sales in future periods. Accounting for this effect would improve the cost-effectiveness of the subsidies and reduce the average cost per metric ton avoided. The change would scale roughly in proportion to the effect on future sales. For example, if one assumes that increasing sales by one unit raises future sales by two units, the average cost of the policy would be roughly half as large as that reported in the table.

As we noted above, Vermont could implement the subsidy as a purchase rebate, purchase tax credit, or dealer subsidy. We model the purchase rebate for simplicity and note that the purchase rebate is probably more effective than a tax credit for reasons discussed above. A dealer subsidy may also be less effective if consumers react more strongly to a change in vehicle prices when they can see the rebate on the sales receipt. However, we are not aware of research that has compared the approaches in a rigorous manner.

The final caveat is that the results reflect consumer choices among vehicles that were available in 2015. Consequently, the results are relevant for the near future, when the set of vehicles and charging infrastructure are not too different from conditions in 2015—perhaps into the early 2020s. As plug-in options and charging infrastructure expand in the future, the change in sales caused by a given subsidy level would likely increase. This consideration, in addition to the prevalence of charging stations, likely causes us to underestimate the effects of a subsidy. As we noted, the idiosyncrasy of Vermont's market pushes the results in the other direction.

The cost of the subsidy per metric ton of CO_2 emissions reduction is about $200. This amount is similar to estimates from some recent programs, such as the 2008 Cash for Clunkers program (Li et al. 2013).

Several attributes of the policy limit the cost-effectiveness. First, most of the subsidy expenditure goes to vehicles that would have been purchased anyway. For example, with the $1,000 subsidy, 223 (92 percent) of the 243 plug-in vehicles would have been purchased without the subsidy; only 8 percent of the subsidy actually increases plug-in sales. This is typical of purchase subsidies, because it is usually difficult, if not impossible, to prevent large shares of the subsidy from going to purchases that would have occurred anyway.Second, the subsidy decreases the average fuel economy of non-plug-ins. This effect means that the emissions reduction caused by the subsidy is less than the emissions reduction one would obtain by simply multiplying the change in plug-in sales by the emissions difference between plug-ins and non-plug-ins.

Third, the dealers capture some of the subsidy for reasons discussed above. The simulation results suggest that this effect is small, especially for the higher subsidy levels considered.

Finally, the subsidies would be less cost-effective than indicated in the table if one accounts for the interaction between the subsidy and the ZEV program, which sets a target for total plug-in sales for Vermont and the other participating states. Because the program effectively fixes total sales in those states, an increase in plug-in sales in Vermont would be offset by a decrease in sales in other participating states.[78] This consideration could mean that the Vermont subsidy would reduce CO_2 emissions from Vermont but would not reduce global emissions.

Appendix B: Model Descriptions

B.1. RFF-DR CGE Model Description

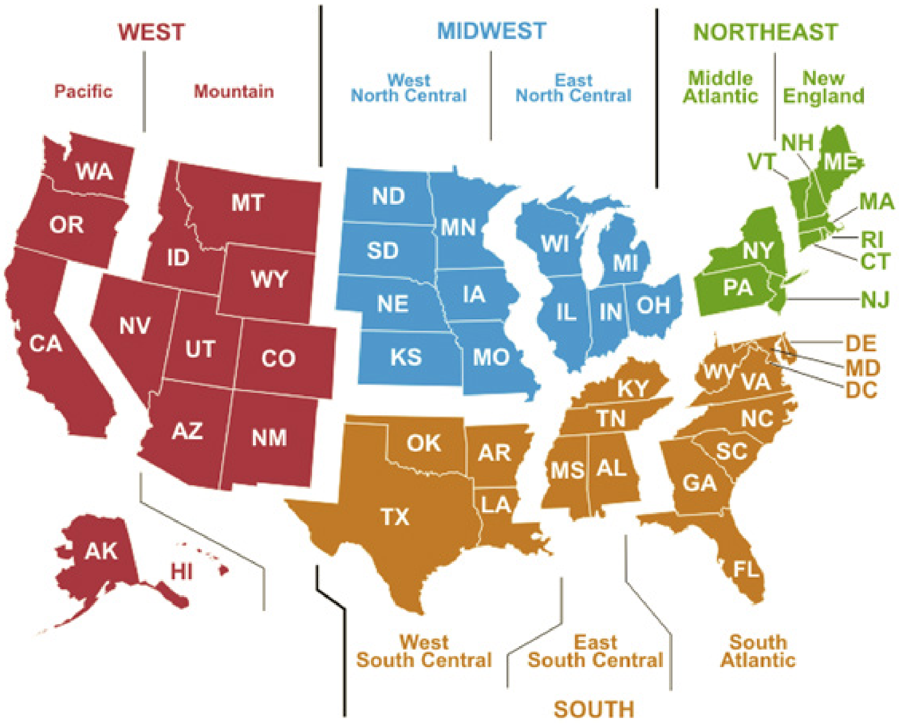
The RFF-DR CGE model shares many features with the Goulder-Hafstead Energy-Environment-Economy (E3) model.[79] Each regional economy is modeled as a collection of forward-looking agents: firms representing distinct industries within that region, a single representative household for that region, and regional and federal governments. The model captures the interactions among agents both within and across regions and solves for market-clearing prices in each period. Each agent has perfect foresight, and the model is solved at annual intervals until it converges to a new steady-state balanced-growth equilibrium. For the purposes of this analysis, we focus on results through the year 2030.

Two features of the Goulder-Hafstead E3 and RFF-DR CGE models distinguish them from other national or regional dynamic environment-related CGE models. These features make them especially well suited for analysis of carbon pricing policies at the national or state level. First, the models combine relatively detailed treatment of energy supply and demand with a detailed treatment of the tax system. This detailed treatment allows the model to evaluate the critical interactions between climate policy and state and federal taxes and spending. These interactions play a fundamental role in determining the economic costs of climate policy.

Second, the model includes the adjustment costs associated with the installation or removal of physical capital at the region-industry level. These costs affect the pace of capital reallocation across industries within and across regions and ultimately affect the speed at which each regional economy responds to a new national or regional climate policy. In addition, the adjustment costs are necessary to model the differential impacts of environmental policy on profits and asset values across industries and regions.

For this analysis, the RFF-DR CGE model breaks the United States into six regions: Vermont, New England Census Division (less Vermont), Middle Atlantic Census Division, Midwest Census Region, South Census Region, and West Census Region. Figure B.1 displays census regions and divisions.

Figure B.1. Census Regions and Divisions



Source: EIA (2018).

Regional social accounting matrices (SAMs) from the IMPLAN Group provide information on market flows and nonmarket financial flows among firms, consumers, and the government (IMPLAN 2017).[80] For this analysis, industrial sectors are aggregated into 18 industries that produce distinct commodities. Table B.1 displays the unique industries and commodities in the RFF-DR CGE model. The IMPLAN data are augmented with information on production, physical consumption, and total expenditures by energy good from the US Energy Information Administration's State Energy Data System (EIA 2018b, EIA 2018c, EIA 2018d). The regional SAMs include data on total exports and imports to other regions within the United States for each commodity but do not include information on state-to-state or region-to-region trade flows. To capture these flows in the economic modeling, we estimate a trade matrix to be consistent with domestic exports and imports of each commodity. Fixed emissions coefficients for carbon dioxide are calculated using EIA data on emissions by state by sector (EIA 2018d) and fixed emissions coefficients for criteria air pollutants are calculated from EPA data on pollutant emissions by major source (EPA 2018b). Finally, we use Bureau of Economic Analysis data to convert personal consumption expenditures by commodity into consumption spending on 24 distinct consumer goods (BEA 2018). All data are from 2015.

Table B.1. Industry and Consumer Goods in the RFF-DR CGE Model

Industry	Consumption Goods
Oil Extraction	Motor Vehicles
Gas Extraction	Furnishings and Household Equipment
Coal Mining	Recreation
Electricity Generation	Clothing
Electric Transmission and Distribution	Health Care
Natural Gas Distribution	Education
Petroleum Refining	Communication
Other Mining and Mining Services	Food
Farms, Forestry, Fishing	Alcohol
Construction	Motor Vehicle Fuels (and lubricants and fluids)
Nondurable Manufacturing	Fuel Oil and Other Fuels
Chemicals, Plastics, Rubber, and Nonmetallic Mineral Products	Personal Care
Durable Manufacturing	Tobacco
Trade	Housing
Transportation	Water and Waste
Communication and Information	Electricity
Services	Natural Gas
Real Estate and Owner-Occupied Housing	Public Ground Transportation
	Air Transportation
	Water Transportation
	Food Services and Accommodations
	Financial Services and Insurance
	Other Services
	Net Foreign Travel

B.2. RFF Incidence Model Description

To analyze the distributional impacts of Vermont climate policies across different households, we employ the RFF incidence model. This is a microsimulation model that links to the RFF-DR CGE model to study the impact of climate policies across income groups and geographic locations. The RFF-DR CGE model provides general equilibrium estimates of expenditures and income changes in response to a Vermont climate policy, and the RFF incidence model estimates how those changes affect different households across Vermont. The RFF incidence model looks only at the initial effects of a climate policy, which include shifts in consumption and production in response to carbon pricing and the use of carbon price revenue. Longer-term effects, which include adjustments to the capital stock, are not included. The model also looks only at policy costs and does not consider the environmental benefits of reduced greenhouse gas and criteria air pollutant emissions. The RFF incidence model follows a similar methodology to that employed in Williams et al. (2014, 2015) to estimate the incidence of a national carbon tax, described in detail in Gordon et al. (2015). The model has been augmented to estimate the incidence of state carbon pricing policies at substate levels.

The fundamental structure of the RFF incidence model is as follows. The RFF-DR CGE model provides aggregate changes in welfare in Vermont due to carbon pricing, which can be decomposed into changes in welfare stemming from changes in the prices and quantities of consumption goods (the model provides results for 24 consumption goods categories) and changes in welfare stemming from changes in income (the model provides results for six income categories). The RFF incidence model estimates the initial level of expenditures and income for households in each income quintile and region in Vermont. The baseline levels of expenditure and income from the RFF incidence model and the aggregate changes in expenditure and income from the RFF-DR CGE model can then be used to approximate the welfare change (by summing the change in consumer and producer surplus) for households in each income quintile and region of Vermont.

Welfare impacts, in dollars per household, are presented for each quintile and region and broken down by consumption good and income type. The changes in welfare associated with the changes in expenditures on direct energy goods (electricity, heating oil, natural gas, and gasoline) are presented by energy source. The change in welfare associated with changes in expenditure on non–direct energy goods is aggregated. The welfare changes associated with income are broken down into capital, labor, transfers, lump-sum rebates (if included in the policy scenario), lump-sum taxes,[81] and trade adjustments.[82]

List of Figures, Tables, and Text Boxes

Figures

Tables

Text Boxes

Notes

1 Electricity-related emissions have grown over 230 percent between 2011 and 2015 and account for about 57 percent of the increase in emissions between 2011 and 2015. One primary cause of this increase is the shutdown of the Yankee nuclear power plant.

2 **https://governor.vermont.gov/press-release/bipartisan-group-governors-leading-climate-change**; **https://obamawhitehouse.archives.gov/the-press-office/2015/03/31/fact-sheet-U.S.-reports-its-2025-emissions-target-unfccc**.

3 **https://legislature.vermont.gov/statutes/section/10/023/00578**

4 For this analysis, we consider all nonpricing policies that received a quantitative emissions reduction estimate in the July 2018 Vermont Climate Action Commission (VCAC) Report to the Governor. This is a comprehensive list of over 30 policies, which themselves may take significant political will to implement. The quantitative emissions reduction estimates for nonpricing policies are not produced by RFF, but come from the VCAC report. In addition, we include an assumption that the Vermont Renewable Energy Standard (RES) is increased to 100 percent by 2030, instead of the current target of 75 percent by 2032. RFF does estimate emissions reductions from the RES increase.

5 There is growing evidence that nonpricing policies have large economic costs and may be less effective at reducing emissions than originally predicted. For example, Fowlie et al. (2018), using a large-scale randomized experiment, found that a weatherization program in Michigan produced energy savings that were only one-third as large as initially projected (and the program delivered a negative return on investment). And in 2017, the California Air Resources Board forecast that a policy that "relies on prescriptive measures to achieve the SB32 target and does not include any carbon pricing mechanism" would result in costs that were 16.4 times greater than the proposed plan that included a cap-and-trade program (CARB 2017).

6 All households are different. Our distributional results break out the effects by income group and by county, but don't capture variation within an income group or a county (they only report the average effect within a given income group or county). Some households with particularly high energy expenditures, such as those with very long commutes, may not be fully compensated by the rebates. Further, our county-level analysis suggests that rural counties are worse-off, on average, than urban counties under all forms of carbon pricing, but low-income households in those rural counties would be better off than the average household in that county if revenues were returned through rebates.

7 For consistency, we report all dollar values relative to values in 2015; to convert 2015$ into 2018$, To convert 2015$ to 2018$, increase the dollar value by 6.34 percent. For example, $19 in $2015 is $20.20 in $2018 (BLS 2019). See **http://www.rff.org/blog/2017/calculating-various-fuel-prices-under-carbon-tax** for a calculator to convert carbon prices into changes in various fuel prices. For example, a $20 carbon price is equivalent to a gasoline tax of $0.18 per gallon.

8 We do not consider carbon pricing policies that cover the electricity sector, for two reasons. First, if Vermont were to remain in RGGI, an additional carbon price on electricity in Vermont would reduce demand for allowances and allow for power sector emissions to increase in neighboring states, completely offsetting all reductions in Vermont. Second, Vermont has very little in-state electricity generation from fossil fuels, and it is difficult to devise carbon pricing policies that provide an incentive to

reduce power sector emissions in jurisdictions outside of the carbon pricing policy.

9 In December 2018, Vermont, with other Northeast and Mid-Atlantic states, announced it would design a policy proposal to cap CO2 emissions from the transportation sector through the Transportation and Climate Initiative (TCI). The policy proposal has not been designed as of January, 2019; we chose to model the program as a cap-and-trade program covering only the transportation sector. The Western Climate Initiative (WCI) is a North American cap-and-trade program that includes California and the province of Quebec; for this analysis, we assume that Vermont links its transportation and heating emissions to this program. Under both cap-and-trade programs, we assume allowance prices follow the WCI minimum allowance price. In 2025, the allowance prices are projected to be $19.43 (in 2015$). The ESSEX Plan is a carbon tax proposal put forward by a coalition of businesses and nonprofit groups that covers most non-electricity emissions in Vermont. Starting at $5 in 2020 and rising at $5 per year, the carbon price will be $30 in 2025 (in 2015$). The high price path is presented for illustrative purposes and its inclusion should not be interpreted as an endorsement of that pricing option.

10 The back-of-the-envelope calculation for combined pricing and nonpricing policies uses our quantitative estimates for carbon pricing and then adds the median estimate for nonpricing reductions from VCAC recommendations and a more stringent RES policy. Actual emissions reductions from each of these policies taken by itself could be higher or lower than projected. Importantly, carbon pricing is likely to reduce the effectiveness of nonpricing policies and vice versa. Therefore, reductions from the combined policy are more likely to be lower than projected than to be higher, though either is possible.

11 The health impacts of criteria air pollutants depend on the ambient concentrations of these pollutants in the air (which in turn depend on pollutant emissions both from within the state and from elsewhere). We only model changes in emissions, not concentrations. Also, we do not attempt to model changes in other types of pollutants such as lead and mercury.

12 These benefit levels assume that the value of local criteria air pollutant emissions reductions is captured entirely by Vermont and not by states downwind from Vermont.

13 A 2014 study conducted by REMI found positive economic impacts for a Vermont carbon tax with lump-sum recycling. REMI has also produced similar results for national carbon tax policies (REMI and Synapse, 2014). However, REMI's national-level results are inconsistent with those in most of the peer-reviewed literature on carbon taxes (see Barron et al. 2018 for a summary of results from 11 economic models). Moreover, an expert panel on economy-wide modeling convened by EPA's Science Advisory Board noted that while models structured like the REMI model "can be very useful for short-term forecasting, using them to analyze the effects of policy changes, particularly over the long run, can be misleading" (EPA SAB 2017).

14 The analysis uses a model in which there is no distinction between workers and hours worked. As shown in Hafstead et al. (2018), interpreting changes in total labor demand from these types of models as changes in employment levels ignores changes in hours per worker. If hours per worker change in response to a carbon policy, then the reported changes in labor demand from a full employment model cannot be interpreted as changes in the level of jobs in the state.

15 If carbon prices are high, the change in aggregate economic welfare is negative, even when revenues are used to reduce taxes on wage income.

16 See footnote 5.

17 The SCC measures the damages, in dollars, of emitting an additional ton of carbon

dioxide into the atmosphere. There is significant debate over the value of the SCC, with much of the focus on the choice of the discount rate used to evaluate the cost of future damages today and whether to measure global benefits or only national or subnational benefits. In this analysis, we use an SCC of $48 in 2020 (in 2015$) and growing to $57.16 in 2030 (in 2015$), reflecting the average SCC, using a 3 percent discount rate, from the Obama administration's Interagency Working Group's 2016 update. Further, we assume that Vermonters care about global well-being, and therefore we use global estimates for the social cost of carbon. The direct subnational and national impacts will vary tremendously. Even in Vermont, climate change will have differential impacts on businesses and households. Agriculture may experience longer growing seasons, while ski resort operations may be forced to shut down during shorter winters. It is beyond the scope of this report to project impacts of climate change within Vermont.

18 For each type of benefit, the monetary value estimated for a given time period is a net present value of the immediate and future benefits caused by reducing emissions in that period.

19 For example, the Vermont Department of Health estimates that the public health benefits of reduced particulate emissions from weatherizing one home is $1,026 annually (VT DEH 2018).

20 As mentioned previously, we do not measure the economic impacts of nonpricing policies. The distributional impact of nonpricing policies will vary by policy. A 2016 National Bureau of Economic Research conference "Energy Policy Tradeoffs between Economic Efficiency and Distributional Equity" featured a number of papers on the impacts of various nonpricing policies on low-income households. The general pattern of results suggests that reducing emissions via pricing is less regressive than nonpricing policies that would generate similar levels of emissions reductions. (**https://conference.nber.org/conferences/2016/EPTf16/summary.html**)

21 See Sec. C.110 Implementation of Preliminary Recommendations of the Vermont Climate Action Commission; Executive Order No. 12-17.

22 "Carbon pricing" as used in this report encompasses both carbon taxes and cap-and-trade programs.

23 Federal Reserve Economic Data, Federal Reserve Bank of St. Louis, **https://fred.stlouisfed.org/series/VTRGSP**.

24 The share of emissions in Vermont has been quite stable between 1990 and 2015, though the share from electricity consumption has increased in recent years due to the closure of the Vermont Yankee nuclear plant.

25 The state's statutory, Under2 MOU, and NEG/ECP targets were all defined relative to 1990 emissions levels. Here, we have made those targets relative to 2005 levels for a consistent base year throughout the report.

26 **https://legislature.vermont.gov/statutes/section/10/023/00578**.

27 **https://governor.vermont.gov/press-release/bipartisan-group-governors-leading-climate-change**; **https://obamawhitehouse.archives.gov/the-press-office/2015/03/31/fact-sheet-U.S.-reports-its-2025-emissions-target-unfccc**.

28 **https://unfccc.int/news/under-2-mou-a-subnational-global-climate-leadership**; **https://climatechange.vermont.gov/climate-pollution-goals**.

29 **http://www.cap-cpma.ca/data/Signed%2039-1En.pdf**; **https://climatechange.vermont.gov/climate-pollution-goals**.

30 **https://www.efficiencyvermont.com/about/history**.

31 Also see **https://publicservice.vermont.gov/energy_efficiency/cbes** and **https://publicservice.vermont.gov/energy_efficiency/rbes**.

32 **https://publicservice.vermont.gov/energy_efficiency/buildingenergy_labeling**.

33 **http://programs.dsireusa.org/system/program?fromSir=0&state=VT**.

34 For a discussion of electric vehicle deployment in Vermont, including an RFF simulation of the effects of electric vehicle purchase incentives, see Appendix A.

35 **https://publicservice.vermont.gov/content/act-174-recommendations-and-determination-standards**.

36 Also see **https://puc.vermont.gov/electric/net-metering**.

37 State of Vermont, Executive Department, Executive Order No. 12-17, July 2017, **https://governor.vermont.gov/sites/scott/files/documents/EO%2012-17%20-%20Climate%20Action%20Commission.pdf**.

38 There is growing evidence that nonpricing policies may be less effective at reducing emissions than originally predicted. For example, Fowlie et al. (2018), using a large-scale randomized experiment, found that a weatherization program in Michigan produced energy savings that were only one-third as large as initially projected (and the program delivered a negative return on investment).

39 30 V.S.A. § 8002-8005.

40 The current Vermont RES Tier 1 requirement is 75 percent renewable energy by 2032. See **https://puc.vermont.gov/electric/renewable-energy-standard**.

41 The following lists of policy recommendations are drawn from Vermont Climate Action Commission, Executive Order No. 12-17 Report to the Governor, July 2018.

42 The settlement agreement that stemmed from the diesel fuel vehicle emissions scandal set aside money for Volkswagen to compensate owners of the affected vehicles and for the company to invest in electric vehicles. The agreement also allocates funds to each state that the state can use to fund projects that are expected to reduce emissions from diesel fuel vehicles. A state can use up to 15 percent of its allocation to promote plug-in vehicles.

43 For example, the Vermont Department of Health estimates that the public health benefits of reduced particulate emissions from weatherizing one home is $1,026 annually (VT DEH 2018).

44 **https://conference.nber.org/conferences/2016/EPTf16/summary.html**.

45 Vermont does not currently offer statewide plug-in vehicle subsidies, but its renewable energy standard incentivizes utilities to promote plug-in vehicles. As a result, many utilities in Vermont subsidize plug-ins.

46 Appendix A provides details of this analysis.

47 The model includes a number of simplifications. As discussed in Appendix A, these numbers should be considered as rough order-of-magnitude estimates.

48 This simple example assumes that the negative externality is the only market failure (or that other policies have already addressed all other market failures), as does the discussion in the rest of this section. If there are other uncorrected market failures, then an emissions tax alone won’t be the most efficient policy: one would need to combine the emissions tax with an additional policy (or policies) to address the other uncorrected market failures. The example also focuses only on the overall costs and benefits of reducing air pollution, and ignores potentially important issues related to how those costs and benefits are distributed across different individuals.

49 One way to construct such a hybrid design is by adding a price floor and/or price

ceiling to a cap-and-trade program (where the government cuts back the number of permits if the price reaches the floor, or issues additional permits if the price reaches the ceiling). The emissions containment reserve in RGGI serves the same purpose. Or one could add a tax adjustment mechanism to a carbon tax (which would automatically increase the carbon tax rate if emissions exceed a prespecified target range and/or reduce the tax rate if emissions fall below that range). See Murray, Newell, and Pizer (2009) for a discussion of hybrid cap-and-trade policies and Hafstead, Metcalf, and Williams (2017) for a discussion of hybrid carbon tax policies.

50 Some nonpricing policies are more flexible than others, but no nonpricing policy can provide the same combination of incentives and flexibility as a broad price signal.

51 The effect on carbon pricing revenues is theoretically ambiguous: a higher carbon price means more dollars per ton of carbon subject to the carbon price but also larger emissions reductions (and thus fewer tons subject to the price). The former causes revenues to rise as the price rises, but the latter causes revenues to fall, so whether carbon pricing revenue rises or falls overall depends on which effect dominates. In practice, the former effect is very likely to dominate (at least for the range of carbon prices considered in this study), causing revenues to rise as the price rises.

52 Many early cap-and-trade programs featured the “free allocation” of allowances to firms. Subsequent trade between firms with and without enough allowances would determine the market price. More recent cap-and-trade programs, including RGGI, sell the allowances through auctions. In the case of free allocation, the program generates zero gross revenues for the participating governments. For this study, we assume that all cap-and-trade programs auction 100 percent of the allowances and therefore raise the same amount of revenue as a carbon tax with the same carbon price.

53 For a more thorough description of each model, see Appendix B.

54 The model does not capture changes in other forms of pollution, such as lead and mercury pollution.

55 The RFF-DR CGE model is a full employment model: the wage adjusts such that labor demand equals labor supply. As shown in Hafstead et al. (2018), interpreting changes in labor demand as changes in employment levels ignores changes in hours per worker. If hours per worker change in response to a carbon policy, then the reported changes in labor demand from a full employment model cannot be interpreted as changes in the level of jobs in the state.

56 These pricing options were chosen for illustrative purposes. The inclusion of any policy option in our analysis should not be interpreted as an endorsement of that pricing option.

57 As discussed earlier, carbon cap-and-trade is equivalent to a carbon tax as long as the two systems have the same carbon price (permit price or tax rate). But the market price of allowances in a cap-and-trade program is inherently uncertain. In the case of the WCI, the market price will depend on the number of participants (states or provinces) and the number of complementary policies in the future. In the past, the allowance price has cleared at or near the minimum reserve auction price. We anticipate that this will continue in the near future, as we expect that California’s Air Resource Board will continue to pursue policies that reduce demand for allowances in the system such that the allowance price will remain at the minimum reserve price.

58 The leakage rate is defined as the change in CO_2 emissions in Northeast states (not including Vermont) divided by Vermont’s CO_2 emissions reductions. The model does not measure methane leakage. However, because we do not consider policies that expand pricing beyond RGGI in the electricity sector, we would not expect any signifi-

cant change in methane emissions in neighboring Northeast states.

59 Price changes are reported relative to a numeraire price in the RFF-DR model. We have chosen a non-carbon intensive price (the wage rate of workers in the West Census Region) as the numeraire price.

60 See Goulder et al. (2018) for a detailed discussion of the use- and source-side economic welfare costs.

61 Recall that in the discussion above on macroeconomic impacts, the state GDP impact in 2025 was $9.8 million to $33 million (in 2015$).

62 There is one exception: quintile 4 experiences small positive changes in economic welfare from the ESSEX Plan price path.

63 These pricing options were chosen for illustrative purposes. The inclusion of any policy option in our analysis should not be interpreted as an endorsement of that pricing option.

64 This finding is consistent with the results for national carbon pricing policies across a range of models. See Barron et al. (2018) for a discussion.

65 In the RFF-DR model, the change in economic welfare is positive under the labor tax cut scenario only if the carbon price is relatively low. Under the Medium carbon price path and labor tax cuts, we find that the change in economic welfare is essentially zero; under higher carbon prices and labor tax cuts, we find that the change in economic welfare is negative.

66 These pricing options were chosen for illustrative purposes. The inclusion of any policy option in our analysis should not be interpreted as an endorsement of that pricing option.

67 A Vermont carbon price policy that taxes electricity consumption would create unintended interactions with the RGGI cap-and-trade program. Any reduction in Vermont electricity demand would reduce demand for allowances, lower the RGGI price, and increase emissions in other RGGI states that would largely offset any reduction in Vermont's consumption-based electricity emissions.

68 We consider a policy where Vermont joins the Western Climate Initiative by itself to be a Vermont-only policy because WCI exists in our business-as-usual case and we are projecting the differences between current WCI and WCI + Vermont.

69 **https://www.transportationandclimate.org/nine-states-and-dc-design-regional-approach-cap-greenhouse-gas-pollution-transportation**.

70 Emissions reductions from the combined policy will likely be somewhat smaller than the sum of reductions from pricing alone and reductions from nonpricing policies alone, because they target some of the same emissions, and thus adding reductions is implicitly double-counting some reductions. To take an extreme example, if carbon pricing by itself would achieve more than a 50% emissions reduction, and the same is true for nonpricing policies, the combination obviously wouldn't yield a reduction of more than 100%. This point is less obvious for smaller reductions, but the same principle will tend to apply.

71 This value is equal to the median estimates for both VCAC recommendations and the RES policy in 2025.

72 VCAC does not provide nonpricing policy reduction estimates, and therefore we simply assume that the policies will achieve reductions equal to the 2025 high-end range by 2030; this assumption applies 2.4 $MMTCO_2e$ additional reductions in 2030. We do have a 2030 estimate for the RES policy, and so we again use the median estimate (based on the median between (a) no increase in the RES over the existing RES by

2030, and (b) a full increase to 100 percent by 2030) for that policy in 2030, which is 0.3 MMTCO$_2$e.

73 Estimates for emissions reductions from the VCAC recommendations come from the VCAC report. Emissions reductions from an increase in the state's RES are calculated by this report's authors.

74 This report uses "plug-ins" for all-electric vehicles such as the Nissan Leaf and plug-in hybrids such as the Chevrolet Volt, which have a small gasoline-powered engine.

75 Because of the crediting provisions, these targets are uncertain and depend on the mix of all-electrics and plug-in hybrids used for compliance. Consequently, the actual number of plug-ins sold under ZEV may differ from these numbers.

76 Based on data from the 2017 National Household Travel Survey and from R. L. Polk, we assume that a vehicle is driven roughly 150,000 miles over its lifetime. This number accounts for the probability the vehicle is scrapped and is based on a discount rate of 3 percent. Each gallon of gasoline burned emits 17.6 pounds of CO$_2$, which is taken from the US Energy Information Administration. Plug-in electric vehicles emit no carbon dioxide, which is an approximation based on the fact that Vermont participates in the Regional Greenhouse Gas Initiative, which caps electricity sector emissions from several states. This is an approximation because actual emissions have typically been below the cap. For plug-in hybrid vehicles, we compute the emissions from gasoline combustion using data from **www.fueleconomy.gov** and data generously provided by the Vermont Energy Investment Corporation.

77 Another possible reason for this discrepancy is that the Leaf is all-electric, whereas plug-in hybrids appear to be relatively more popular in Vermont than all-electrics. In addition, the relative scarcity of public charging stations in Vermont could explain this result.

78 In principle, if many states offer large subsidies, national sales could exceed the target. In that case, an additional subsidy in Vermont could increase total sales.

79 For a complete description of the E3 model, see Goulder and Hafstead (2017).

80 The RFF-DR CGE model uses 51 state (including District of Columbia) SAMs from IMPLAN and aggregates them to the specified regional aggregation.

81 Lump-sum taxes are the residual in the government's budget constraint solved for in the RFF-DR CGE model and are assumed to be collected in a lump-sum manner.

82 Trade adjustments reflect that the state purchases more goods from other regions than it sells to other regions (or vice versa). Examples of economic activities that affect the trade adjustment are investments outside the state or labor conducted outside the state. Trade adjustment income is assumed to be 80 percent capital income and 20 percent labor income.

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