FEBRUARY 2019

Economic Benefits and Energy Savings through Low-Cost Carbon Management

Richard Cowart, David Farnsworth, and Frederick Weston

Challenges, Opportunities, and Means

Over the past five years the consensus of international climate scientists has only deepened the conviction that the world is facing unprecedented challenges associated with climate change, as a result of human activities—principally as a result of the combustion of fossil fuels that emits carbon dioxide (CO_2) and other greenhouse gases (GHGs). Just a few months ago, the United Nations Framework Convention on Climate Change (UNFCCC) warned, "Climate change is the defining challenge of our time, yet it is still accelerating faster than our efforts to address it."[1] The Vermont Climate Action Commission (VCAC), appointed by Governor Phil Scott, concluded that "Global climate change is a fundamental threat to Vermont, to our economy, environment, and way of life."[2] The VCAC delivered some 53 specific policy recommendations for action in Vermont.

The VCAC findings, like those of the study commissions that preceded it, confirm two critical conclusions:

- The impacts of global climate change are advancing rapidly, and Vermont has a role both as a leader and as an actor alongside other states, nations, and cities across the globe in addressing and avoiding the worst consequences of rising greenhouse gas emissions.
- Many of the actions that Vermont can take to reduce global warming pollution will in fact be achievable, affordable, and, in many cases, provide other benefits to families and businesses in our state.

1 United Nations Framework Convention on Climate Change. (April 2018). *UN Climate Change Annual Report 2017*. Bonn, Germany. Retrieved from https://unfccc.int/resource/annualreport/.

2 Vermont Climate Action Commission. (July 2018). *Report to the Governor*. p. 1, Retrieved from https://anr.vermont.gov/sites/anr/files/Final%20VCAC%20Report.pdf. In the brief time permitted for this study, we do not attempt to assess the comprehensive work done by VCAC, the DPS, and many others in recent years. Obviously, a great deal of work has been done to identify promising programs and policies to reduce carbon pollution; we hope simply to shine some light on the principles that should guide decision-makers, and on a few of the leading options now in front of us.

In the 2018 legislative session, the Vermont Legislature called for a study to examine the possible methods, costs, and benefits of using carbon pricing to address the problem of carbon pollution in the state. Resources for the Future (RFF) was commissioned by the legislature's Joint Fiscal Office to conduct that study, using the economic models and approaches available to RFF.[3]

The Regulatory Assistance Project (RAP) has been asked to assess the RFF study and its conclusions, and to offer suggestions for action based on its results and our expertise in energy and climate policy. RAP has, over the past 25 years, examined these issues not only in Vermont but across the globe. Our observations and recommendations are based on that broad base of experience.

For the purposes of this report, in the short time available, we commissioned two expert studies. The first, on low-carbon transportation, was completed by M.J. Bradley & Associates (MJBA), which has conducted several studies on this topic across our region and beyond. The second, on opportunities for energy savings in housing and public buildings, was completed by the Energy Futures Group (EFG), an expert consulting firm based in Hinesburg, Vermont. These studies can be found attached to this report as Appendices A and B, respectively. We are grateful to these two firms for lending their expertise to Vermont and offering leading insights to this review.

What have we found? Based on the plain facts of Vermont's physical and economic conditions, we conclude that an attempt to reduce Vermont's carbon emissions based on carbon pricing alone will cost more, and deliver less, than a program of carbon reductions that is based on practical public policies—policies that attack the main sources of carbon pollution through tailored, cost-effective programs geared to Vermont's families, businesses, and physical conditions.

Decarbonizing Vermont is Especially Challenging

Across the globe, cities, states, and nations are grappling with the multiple challenges of carbon reduction. Although cases vary, when we examine the sources of carbon pollution, the four largest areas are: electric power, transportation, industry, and buildings.

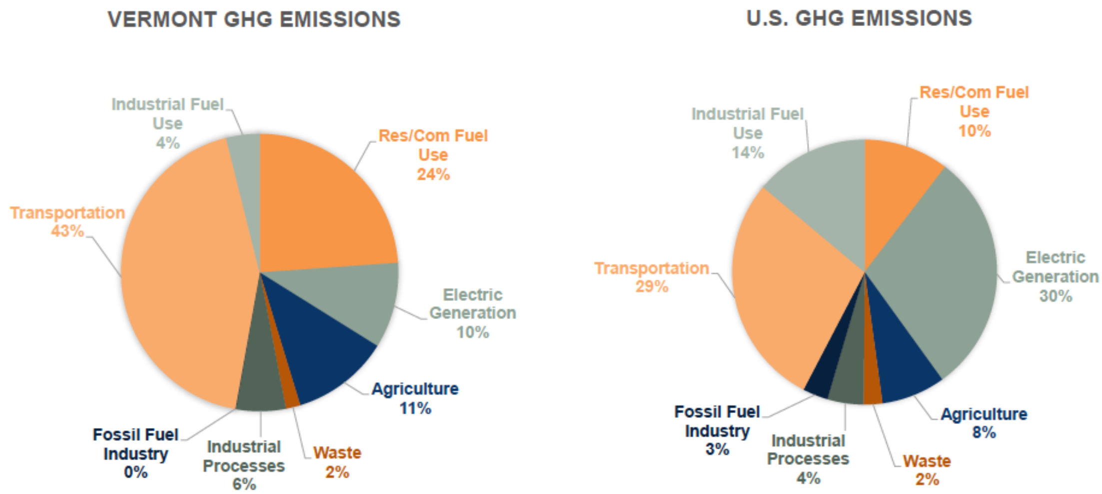
Vermont already has, as a result of our industrial history and clean-energy policies implemented over the past two decades, a relatively low-carbon industrial sector, and an increasingly low-carbon electric power portfolio. This leaves the state with two major opportunity areas to mine for carbon reductions, energy efficiency, and reducing the enormous bill we pay to import fossil energy: light-duty transportation and heating of buildings. See Figure 1.[4]

---

3 Hafstead, Marc A.C., et al. (January 2019). *An Analysis of Decarbonization Methods in Vermont*. Resources for the Future. Retrieved from https://ljfo.vermont.gov/assets/Uploads/e6fdadcf09/DecarbonizationMethodsVT_Report_final.pdf.

4 Hafstead et al., p. 15 (Figure 1.3).

Figure 1. Sources of Vermont and US Greenhouse Gas Emissions



This situation presents us with both good news and a substantial challenge. The good news is that Vermont's electric portfolio is relatively clean, and has the prospect of becoming cleaner over time, even with increased load due to the addition of electric vehicles and high efficiency electric heating systems. In short, we can envision a transition to low-carbon energy services in Vermont based on renewable energy, energy efficiency, and fuel switching from fossil sources to beneficial electrification, especially for vehicles and home heating.

The challenge is that making the shift to electric-based vehicles and low-carbon buildings requires both advanced public policies and actions to be taken by many thousands of Vermont families and businesses. These transitions are, on reflection, harder than the task of creating a low-carbon power supply for our state, but they are the essential next steps on the path to meeting global needs and the climate goals Vermont has adopted.

Is carbon pricing alone the best way to do this? We conclude that it is not.[5]

5 RFF reached a similar conclusion: "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 non-pricing 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)." Halstead et al., p. 11.

A Price on Carbon vs. Cost Per-Ton Avoided: Two Different Things

Putting a price on CO_2 emissions is one of the many useful carbon reduction strategies discussed in this paper, and a key focus of the RFF analysis. A carbon tax and cap-and-trade regimes are two means by which to price carbon; they require those who emit CO_2 to pay for every ton they put into the air. Their object is to change energy investment and demand decisions by raising the cost of climate pollution.

Pricing carbon should not, however, be confused with the *cost per-ton of CO_2 avoided*, a key metric to measure the effectiveness of various carbon reduction strategies or programs. It is the ratio of total program cost to the total tons reduced by the program, and it provides a simple first-level assessment of the relative effectiveness of different strategies. If, for a given level of reduction, one strategy can avoid a ton of carbon for $2 and another can avoid a ton for $1, then the second strategy is preferable, enabling either greater emissions reductions or the same reductions for half the price.

As societies grapple with the challenge of meeting ambitious climate goals, it is particularly important to consider the cost per-ton avoided from a consumer perspective. In some cases–for example in competitive power markets–the *consumer cost per ton avoided* can be much higher than the nominal price of carbon set by the tax or cap-and-trade system. In other cases, the consumer cost can be lower than the carbon price– or example when carbon revenues are used to lower energy bills through energy efficiency programs.

An Important Policy Question: What Does a Climate Policy Cost Consumers per Ton of Carbon Avoided?

Many advocates of carbon pricing begin with the proposition that the main point is to charge for carbon emissions "appropriately" and that carbon reductions will surely follow in the most efficient manner. While carbon pricing is a useful tool in the fight against climate change, there is now substantial experience to suggest that wise **use of the resulting carbon revenues** is equally important, or even more important, if the goal is to actually reduce emissions at the lowest reasonable cost. One of the principal conclusions of the RFF study is that, even if carbon charges were set as high as $100/ton, the reduction in carbon emissions achieved statewide would be only about 10 percent below the expected business-as-usual case.

This seems to present us with an insoluble problem. On the one hand carbon pricing is said by many to be the "best" and "most efficient" way to drive down emissions in line with global targets and Vermont's statutory goals. But on the other hand, as common sense and studies—including even RFF's analysis—conclude, carbon pricing alone will be a weak tool to deal with the realities of consumer behavior, our historic buildings infrastructure, rural settlement patterns, and the many barriers that working families and businesses face in choosing to invest in energy efficiency or other low-carbon options.

But this challenge is not as intractable as it may seem. Fortunately, Vermont decision-makers now have easy access to at least three demonstrations of the ways that **energy pricing can be married to public policies to drive energy savings, carbon reductions, and bill reductions—all at the same time**. We touch on three important examples here, although many more could be given.

Utility Efficiency Programs and Efficiency Vermont

Since the Public Service Board's investigation and initial orders in Docket 5270, Vermont's utilities, regulators, and legislature have developed and supported broad-based programs to help families and businesses save energy at lower cost than the cost of energy supply, significantly lowering the state's power and natural gas bills year-in and year-out for over 25 years. These programs, now delivered by Efficiency Vermont, Burlington Electric Department, and Vermont Gas Systems, have been supported by a modest efficiency charge on consumer bills—a charge that is returned four times in the savings it produces.[6]

Although these programs total about 7 percent of the total cost of utility service (versus over 90 percent for energy supply and delivery), the total efficiency savings realized in Vermont have built up over time to become one of our largest energy service resources. New savings from Vermont's efficiency programs average around 1.5 to 2 percent per year, and these savings are added to those of prior years' investments that are still in place, resulting in an ever-growing wedge of savings over time. By 2018 efficiency programs were avoiding as much as 20 percent of Vermont's electricity demand, which is more electricity savings than Vermont's supplies of solar, wind, wood, and landfill methane power combined.[7] Moreover, cost-effective energy efficiency programs save money for Vermont families and businesses; since 2000, Efficiency Vermont has generated $2.5 billion in electric energy savings, leveraged through programs supported by just $600 million in ratepayer funds. Because Vermont's utility-scale efficiency programs are cost-effective on their own terms, they deliver greenhouse gas reductions as an added benefit, essentially for free.

The Regional Greenhouse Gas Initiative

A globally-leading example of the power of wise use of carbon revenues, in contrast to carbon pricing alone, is the Regional Greenhouse Gas Initiative (RGGI), a carbon cap-and-trade program covering the electric power sector across nine northeastern states. Since 2009, the RGGI states have reduced carbon emissions from the power sector by 40 percent, while enjoying substantial

---

6 This is to say that, for every dollar of *program* investment, four dollars of savings are returned. For every dollar of total cost for efficiency measure, which includes the shares paid by the recipients of the efficiency measures, two dollars of savings are returned. See Efficiency Vermont Annual Report, p. 13. The benefit-cost ratios have generally been in the 3:1 range on a program cost basis and the 1.6:1 range or greater on a total cost basis. See Efficiency Vermont's annual reports for 2014 and 2015 and the report of the independent auditor for the 2011-2013 period, all available for download from the website of the Vermont Public Utility Commission, at https://puc.vermont.gov/energy-efficiency-utility-program/eeu-verification-and-evaluation.

7 Efficiency Vermont's savings rates are subject to independent review by the Public Service Department and the Public Utilities Commission. In its 2017 Annual Report, Efficiency Vermont shows cumulative savings of 16.2% of power demand delivered since 2000. The utility programs operating since 1992 can reasonably be estimated to have delivered at least 4% savings in addition to those delivered by Efficiency Vermont. (Renewables generation fractions are from the latest DPS Comprehensive Energy Plan, p. 189.)

economic growth.[8] International observers are surprised to learn that this been accomplished, not through high carbon prices, but largely through a suite of public policies supported by strategically investing the carbon revenues received at modest carbon allowance auction prices.[9] Vermont led the way with legislation that dedicated its RGGI allowance income to end-use energy efficiency. Other states followed suit, and overall the RGGI states have invested about 60 percent of their carbon allowance revenues to saving energy—and avoiding further carbon emissions in doing so. Recent analyses by RGGI, Inc. and independent researchers have found that the RGGI states have been able to lower carbon emissions while also *lowering* power bills—meaning that, so far, the carbon savings have been delivered at a cost of less than $0 per ton avoided.

Vermont's Weatherization Assistance Program

As nations, states, and citizens engage more deeply with the climate crisis, it quickly becomes apparent that affordability and fairness must be essential features of the policy choices made to reduce our economy's reliance on fossil fuels. These issues, which can be termed questions of "energy justice," must be part of the design criteria for Vermont's decarbonization pathway.[10] Vermont has long delivered several efficiency, fuel assistance, housing, and social programs to improve energy affordability for low-income households. With regard to the building stock, a leading example is the Weatherization Assistance Program. It was created under a federal program in the 1970s in response to the oil crisis, but the legislature increased funding for it significantly in 1990 by creating an "all fuels" charge of 0.5 percent on the gross sales of non-transportation fuels (except wood). Those funds, now channeled through a special Weatherization Assistance Fund, pay for 80 percent of the total cost of the low-income weatherization program. While total funding is far below what is needed even today,[11] the structure of the program is a useful, proven model for the kind of assistance that will inevitably be needed to transform the housing stock for low-income households. It will not be possible, nor would it be fair, to attempt to meet Vermont's climate goals without including programs to meet the energy needs of all Vermont households.

The good news is that evaluations of the Weatherization Assistance Program reveal that these investments save more than they cost[12], and thus can improve economic welfare and human health

---

8 Ceres (2016). *The Regional Greenhouse Gas Initiative: A Fact Sheet*. Retrieved from https://www.ceres.org/sites/default/files/Fact%20Sheets%20or%20misc%20files/RGGI%20Fact%20Sheet.pdf

9 For more information on the use of carbon auction revenues for efficiency, see Cowart, R. (2008). Carbon Caps and Efficiency Resources: How Climate Legislation Can Mobilize Efficiency and Lower the Cost of Greenhouse Gas Emission Reduction. 33 *Vermont Law Review* 201. Retrieved from https://www.raponline.org/wp-content/uploads/2016/05/rap-cowart-carboncapsandefficiencyresources-vermontlawreview-2008-winter.pdf. See also Littell, D., and Farnsworth, D. (2016, May). *Carbon Markets 101: "How-To" Considerations for Regulatory Practitioners*. Montpelier, VT: Regulatory Assistance Project. Retrieved from http://www.raponline.org/document/download/id/8103

10 See discussion of equity and environmental justice in Farnsworth, D., Shipley, J., Sliger, J., and Lazar, J. (2019, January). *Beneficial Electrification of Transportation*. Montpelier, VT: Regulatory Assistance Project, p. 53. Retrieved from www.raponline.org/knowledge-center/beneficial-electrification-of-transportation

11 Even with the additional funding provided by Vermont's fuel charge, the Weatherization Assistance Program treats fewer than 1,000 units per year. In prior reports to the legislature, RAP has recommended raising the charge on liquid fossil fuels to at least equal the efficiency charges on electricity and natural gas in order to speed up the pace of weatherization for low- and moderate-income households. See Regulatory Assistance Project (2011, June). *Affordable Heat: Whole-Building Efficiency Services for Vermont Families and Businesses*. Retrieved from www.raponline.org/wp-content/uploads/2016/05/rap-affordableheatfullreport-2011-08-01-final.pdf

12 Vermont Agency of Human Services (2018). *Weatherization Assistance Program Overview*. Retrieved from

and safety, while reducing carbon emissions at the same time. This is a program design we can build on.

What is Needed Now?

Although Vermont's existing programs to reduce global warming pollution through energy efficiency are among the leaders in the U.S. and indeed, the world, they are not enough. Our state is far from achieving the carbon reduction goals the legislature has adopted, and that climate science tells us that we all need to achieve. Vermont has the opportunity now to build on its knowledge and successes with much more ambitious programs to move away from fossil-fuel-fired heat and to electrify light duty transportation.

It is beyond the scope of this report to set out a definitive list of policy proposals and funding mechanisms sufficient to meet Vermont's climate goals. Some ideas and strong suggestions are included in the commissioned reports that follow, however. Even so, by referring to the three examples given above and to the analyses in the EFG and MJBA studies, clear conclusions emerge to guide decision-makers as they deliberate on—and then take—Vermont's next steps:

- Relying on carbon pricing alone to drive decarbonization in Vermont's transportation and housing sectors will cost more and achieve less than a program of strategic policies to help Vermont families and businesses move to lower-carbon choices.
- Energy efficiency in various forms, including high-efficiency electrification, home insulation and weatherization, and high-efficiency electric transportation are keys to meeting climate goals. "Efficiency First" has long been a Vermont principle, and is likely to remain a cornerstone of the state's climate policies and programs.
- New revenue sources will be needed to co-fund those transformation programs. The good news is that the costs of efficiency and electrification can be offset significantly by the direct savings achievable by lowering Vermont's $2 billion annual fossil fuel bill. But we will need to invest more in order to save more.
- Principles of fairness and affordability—the principles of "energy justice"—can be embedded in programs designed to reduce reliance on fossil fuels; at the very least, a sharp expansion of the Weatherization Assistance Program and parallel energy efficiency measures to assist low- and moderate-income households is warranted.

Finally, Vermont already has deep experience with the kinds of programs and funding mechanisms needed to attack climate pollution, meet legislated climate goals, and demonstrate that solutions can be practical, affordable, and effective. Vermont is widely known for leadership in energy and environmental policy, based both on direct evidence and the state's reputation for resourceful thinking. Vermont now has the opportunity to extend that leadership, influencing reductions in climate pollution far beyond its own carbon footprint. The urgency of the global climate challenge requires picking up the tools at hand, and acting now on the knowledge already available.

---

https://legislature.vermont.gov/Documents/2020/WorkGroups/Senate%20Economic%20Development/Housing%20and%20Homelessness/W~Geoff%20Wilcox~Weatherization%20Assistance%20Program%20Overview%20~2-7-2019.pdf

The Analyses

Transportation

In consultation with RAP, M.J. Bradley & Associates (MJBA) produced *Decarbonizing Transportation in Vermont* (Appendix A of this report), an analysis of three transportation sector carbon reduction strategies:

- Significant electrification of vehicles including (a) light-duty, (b) medium-duty, and (c) heavy-duty vehicles;
- Increased efficiency in remaining new conventional vehicles; and
- Greater use of bio-based renewable fuels in conventional vehicles.

This is not an exhaustive list of potential transportation sector greenhouse gas mitigation measures. However, these strategies would likely be central to any low-carbon action plan in Vermont and thus are useful illustrations of the potential for economic greenhouse gas mitigation in Vermont's transportation sector. In this section, we highlight each one in turn; look at two scenarios that MJBA analyzed; and examine their conclusions regarding costs and benefits.

MJBA's benefit-cost analysis, especially of light-duty transportation electrification, produces very encouraging results. Light-duty electric vehicles in Vermont can become cost competitive with conventional vehicles in roughly the next 10 years at a cost of approximately $16 per metric ton (MT) of greenhouse gas avoided.[13] Through 2050, the required public support in light-duty vehicle electrification could be as low as $3/MT. To put Vermont on this path to electrifying light-duty vehicles, investment of $70 million will be required over the next 10 years, while after 2030, required investment would be only another $3 million.

The economics of electrifying medium- and heavy-duty vehicles are more challenging, and it will require higher levels of investment than those expected for light-duty vehicles. Over $560 million in public investment may be required through 2030, and over $2.9 billion in investment may be required through 2050. This level of investment would avoid over 9 million MT of greenhouse gases by 2050 at a cost as high as $315/MT.

The analysis assumes that current federal new vehicle fuel efficiency standards, also known as corporate average fuel economy or CAFE standards, will stay in place.[14] MJBA concludes that the net benefits of more stringent fuel efficiency standards for conventional vehicles are positive every year, even in the near term. In other words, the annual fuel cost savings from more efficient vehicles are greater than the annual incremental costs of those vehicles.

13 The costs, benefits, and prices calculated by MJBA and EFG are real, in constant 2018 dollars.

14 In August 2018, the US Department of Transportation and US Environmental Protection Agency proposed flat-lining fuel efficiency and GHG emission standards at 2020 levels through 2026. In the absence of certainty as to the outcome of this proposal, MJBA's baseline scenario includes current fuel efficiency and emission requirements through model year 2025 despite the likelihood that these standards when finalized will be less stringent than standards that MJBA has included in the baseline.

MJBA modeled the costs associated with reducing the carbon intensity of traditional transportation fuels as incremental costs. The purchase of these liquid fuels is considered necessary to comply with the modeled carbon intensity targets. The analysis assumes the following levels of fuel carbon intensity reductions: three percent by 2020, eight percent by 2030, and 16 percent by 2050. Reductions are relative to 2010 carbon intensity

MJBA's analysis is limited to on-road transportation[15] and focuses on light-duty, personal vehicles (cars and light trucks), medium- and heavy-duty single unit trucks, transit and school buses, and heavy-duty combination trucks (also known as tractor trailer trucks or semis).[16] Appendix A contains relevant details of measure characterizations, program design features, and input assumptions (e.g., fuel and electricity cost projections, discount rates, average fuel and emissions savings, incentive levels, and program costs).

The analysis looks at two scenarios, a business-as-usual or "baseline" case and an "80x50" case ("80x50" means an 80 percent reduction in transportation emissions by 2050). As noted, the baseline case presumes no change to current CAFE standards and no standards or policies designed to reduce the carbon intensity of traditional liquid fuels. Furthermore, it reflects relatively low levels of vehicle electrification.

The 80x50 case, in contrast, includes annual increases in new vehicle fuel efficiency beyond current standards, annual reductions in the carbon intensity of liquid transportation fuels, and significantly higher levels of electric vehicle penetration than in the baseline case. The 80x50 case is conservative in that it does not reflect enhancements to public transportation or other policy action to limit expected increases in personal-, medium-, or heavy-duty vehicle miles traveled.

MJBA determined that the costs associated with these abatement measures include higher vehicle purchase costs compared to "baseline" vehicles purchases absent these policies.[17] They also include costs associated with electric vehicle charging infrastructure, reducing the carbon intensity of liquid transportation fuels, and supplying additional electricity for electric vehicles.[18]

The analysis concludes that cumulative financial benefits[19] are negative in the short term. This

---

15 It does not consider air travel, non-road freight transport including rail, water, and pipeline, or other non-road vehicles such as equipment for construction, warehouses, and agriculture.

16 This analysis is based on MJB&A's independent report, *Decarbonizing Transportation*, which explores the costs and benefits of a suite of abatement strategies that could be used to significantly reduce greenhouse gas emissions from on-road transportation within the Northeast and Mid-Atlantic region. The total regional values were apportioned to Vermont for this report based on Vermont's share of regional light duty vehicle, and medium and heavy-duty vehicle miles traveled. See Lowell, D., Saha, A., & Van Atten, C. (2018). *Decarbonizing Transportation*. Retrieved from www.mjbradley.com/sites/default/files/UCS%20Final%20Report%20FINAL%2005oct18.pdf

17 Rather than analyzing specific vehicle types, the analysis develops weighted average vehicle types for each of the three vehicle categories.

18 The costs associated with the accelerated adoption of electric vehicles also include the incremental costs required to supply a mix of renewable and natural gas-fired electricity for vehicle charging, and the related costs of battery storage technology to integrate additional variable renewable energy resources (wind and solar). In order to reflect potential integration costs, MJBA assumes storage costs equal to 15 percent of the renewable capacity added each year. This is a conservative approach in that electric vehicles themselves represent storage capacity already paid for and available for purposes of managed charging which could further reduce additional storage costs of accelerated renewable energy adoption.

19 Cumulative financial benefits are the direct net financial benefits to consumers within Vermont that result from the modeled abatement strategies. These net financial benefits are primarily net fuel cost savings, after subtracting the costs of more expensive vehicles and charging

means that incremental annual vehicle and charging infrastructure costs are higher than annual net fuel costs savings through around 2030. This is primarily due to the investment required for electric vehicle charging infrastructure and the higher purchase price of electric vehicles compared to conventional vehicles in the early years.

However, over time, the incremental cost of EVs is expected to fall and the annual financial net benefits turn positive and expand dramatically. The economic benefits that would accrue to all electric utility customers in the study region due to increased utility net revenue (revenue minus costs) from electric vehicle charging could be used to support operation and maintenance of the electrical grid, thus reducing the need for future electricity rate increases.[20] In effect this net revenue would put downward pressure on future rates, delaying or reducing future rate increases, and thereby reducing customer bills.

Buildings

The analysis of potential building efficiency measures described by the Energy Futures Group (EFG) in *Reducing CO2 Emissions from Vermont Buildings* (Appendix B of this report) renders a powerful verdict: namely, that significant reductions in Vermont's CO_2 emissions can be achieved at a *negative cost* per ton avoided. Put another way, the efficiency and heating retrofits that we examined offer savings in their own right, without any consideration of their emissions reductions. These are investments that Vermont should be making for the economic benefit of its citizens anyway. The carbon reductions come for free.

RAP asked the EFG to analyze five building efficiency measures. This is not, of course, an exhaustive list of potential measures, but rather a representative set likely to yield significant savings and cover a broad range of Vermont's housing stock and heating needs. They are:

- Residential low-income weatherization of oil- and propane-heated homes;
- Residential non-low-income weatherization of oil- and propane-heated homes;
- Retrofitting of cold climate heat pumps into homes heated with oil or propane;
- Retrofitting heat pump water heaters into homes whose water is heated with oil or propane; and
- Retrofitting schools with wood pellet boilers to displace oil heat.

Refer to Appendix B for detailed measure characterizations, program design features, and input assumptions (measure lives, fuel and electricity cost projections, discount rates, average measure fuel savings and emissions reductions, incentive levels and program costs, participation levels, electric end-use load shapes, etc.).

EFG assessed the cost-effectiveness of each of the five measures from two different perspectives:

---

infrastructure for EVs.

20 Note that the grid benefits of added demand from EV charging depend crucially on whether the rates and hours of charging are time-controlled so they align with low-cost power periods and avoid driving up more expensive system peaks.

- **A "total cost" perspective**: This compares the total cost of a measure—both the portion of the measure cost covered by a program rebate and the remaining measure cost paid by the participating customer, plus any additional program costs (for administration, marketing, quality control inspections, evaluation, etc.)—to the value of the energy benefits produced.
- **A "program cost" perspective**: This compares just the cost of running a program–the sum of the rebate offered plus any additional program costs (but excluding the customer contribution to the capital cost of the measure)—to the value of the energy benefits produced.

For both of these analyses, EFG calculated the average per unit net present value (NPV in 2018 dollars) of the lifecycle benefits, costs, and net benefits of each measure. These were then multiplied by the number of measures assumed to be installed and to that product were added the NPVs of the non-rebate program costs. For simplicity's sake, the same number of measures are assumed to be installed in each of the next 10 years. The NPV calculations were performed using the Efficiency Vermont cost-effectiveness screening tool, with the tool's default 3 percent real discount rate.

The results are cost-effectiveness analyses that compare all costs to only the energy system benefits. We took this conservative approach in part because of resource and time constraints but also so as to emphasize the direct energy bill impacts—that is, the economic benefits to the state—of the measures. Other benefits that we did not take into account, but which are nevertheless very real, include (1) the value of avoided environmental externalities, (2) the value of increased flexibility to the grid associated with the controlled use of heat pumps and heat pump water heaters, (3) the value of other non-energy benefits to consumers (e.g., improved comfort, improved health and safety), and (4) the risk-mitigating value of efficiency measures.

The following table (which is also Table 4 of the EFG report) presents the cost-effectiveness results (in millions of 2018 dollars) for the 10-year programs. The analyses show that each of the measures can provide at least $19 million in net cost savings to Vermont consumers from the program perspective and all can provide more than $10 million in net cost savings to consumers from the total cost perspective.

Table 1: Program-Level Cost-Effectiveness (millions of 2018$)

	Total Cost Perspective				Program Cost Perspective			
Measures	NPV Costs	NPV Benefits	NPV Net Benefits	BCR	NPV Costs	NPV Benefits	NPV Net Benefits	BCR
Efficiency								
Non-low income weatherization	$281	$348	$67	1.24	$159	$348	$189	2.19
Low Income weatherization	$152	$195	$42	1.28	$152	$195	$42	1.28
Electrification								
Cold Climate Heat Pumps	$306	$316	$10	1.03	$167	$316	$149	1.89
Heat Pump Water Heaters	$27	$49	$22	1.81	$30	$49	$19	1.62
Biofuels								
Wood Pellet boilers for schools	$20	$46	$26	2.26	$16	$46	$30	2.84

***NPV = net present value; BCR = benefit-cost ratio**

The next table (which is also Table 5 of the EFG report) presents the total lifetime CO_2 emissions reduction that each 10-year program should provide, the average annual program cost (budget), and the levelized costs per metric ton of CO_2 reduced (i.e., avoided).

Table 2. CO_2 Emission Reduction Potential and Its Net Cost

Measures	Lifetime CO2 Reduced from Measures Installed over 10 Prog Yrs (Metric Tons)	Average Annual Program Budget (millions of 2018 $)	Levelized $/Ton of Lifetime CO2 Reduced (Total Cost Perspective)	Levelized $/Ton of Lifetime CO2 Reduced (Program Perspective)
Efficiency				
Non-low income weatherization	1,458,078	$18	($75)	($212)
Low Income weatherization	817,850	$18	($84)	($84)
Electrification				
Cold Climate Heat Pumps	1,795,531	$19	($8)	($119)
Heat Pump Water Heaters	314,094	$3	($97)	($83)
Biofuels				
Wood Pellet boilers for schools	340,222	$2	($131)	($152)

The bottom line, as noted at the outset, is that the net levelized cost per ton of carbon emissions reduction is negative for all measures, from both perspectives. This means that *all five of the measures analyzed make economic sense to pursue even if addressing climate change were not a motive*.

Conclusion

The MJBA and EFG analyses offer robust empirical support for programs to cost-effectively shrink Vermonters' energy bills and put the state on a trajectory to meet its expressed greenhouse gas emissions reduction goals. This isn't a surprise: the *clean* course of action has long been shown to also be the *least-cost* course of action.

But that doesn't mean it will be easy. It requires a commitment of the kind that Vermonters have risen in the past to accept. We've understood that return on investment isn't always immediate, but that it's most secure when it promotes the long-term public good.

The potential revenues from carbon pricing that RFF calculates and the potential costs of the carbon-reducing strategies that EFG, MJBA, and RAP have evaluated are not strictly comparable, primarily because the analysts have chosen different base years for expressing the real (in economic terms) costs and benefits. The base year for the RFF analysis is 2015; MJBA and EFG used 2018.[21]

21 Their comparability is also affected by how they treat the host of input assumptions and related interactions that drive outcomes in their models.

But it's nevertheless possible to get a sense of the relative magnitudes of the revenues and costs at issue. RFF forecasts a wide range in potential revenues from some form of carbon pricing (see Table 4.3 of the RFF report[22]). In their analysis, the projected carbon price path that produces the lowest trajectory of annual gross carbon revenues for Vermont is that of the Western Climate Initiative (WCI), starting at $99.4 million in 2020, rising to $120.8 million in 2025, and increasing further to $147.0 million in 2030 (in millions 2015$).

The cumulative, 2018-2030 public (programmatic) investment in light-duty vehicle strategies analyzed by MJBA is $70 million (in 2018$).[23] The cumulative 10-year public investment in the building and heating strategies examined by EFG is $600 million (also in 2018$).[24] Again, we emphasize that the amounts in the MJBA and EFG reports cannot be directly compared with those in the RFF report, but there appears to be significant room under the WCI price path to fund the kinds of investments that have been posited above.

Table 3. Programmatic Cost/Ton of CO_2 Avoided

WCI Carbon-Pricing Only	$403
Light-Duty Vehicle Strategies	$16
Buildings & Heating Strategies	-$57

Lastly, the costs per ton of CO_2 avoided of the various approaches are revealing (though they must also be qualified against direct comparison). The light-duty vehicle strategies suggested by MJBA would avoid 4.4 million metric tons of greenhouse gases over the 10 years to 2030 at a program cost per ton of carbon dioxide avoided of $16 (2018$).[25] The building and heating strategies suggested by EFG would avoid GHGs at a program cost of *negative* $57 per ton (2018$).[26] In contrast, the cost per ton of CO_2 avoided by pricing only (in this case, the WCI price) would be $403 (2015$).[27]

A central conclusion to be drawn from these studies is that a wide range of readily available, low- or even negative-cost carbon-reducing investments can save Vermonters money and put the state on a path to meeting its climate goals. Moreover, the near-term costs of those programs are moderate and lower than the cost of trying to achieve meaningful greenhouse gas emissions reductions through carbon pricing alone.

22 Hafstead et al., p. 42.

23 See Appendix A, p. 13 (Table 2).

24 See Appendix B, p. 15 (the sum of annual program costs times ten; Table 5).

25 See Appendix A, p. 13 (Table 2).

26 See Appendix B, p. 15 (the weighted average of the program costs per ton of CO2 avoided).

27 Halstead et al., p. 84 ($120.8 million divided by economy-wide savings of 0.3 million metric tons; Table 4.17).

RAP® Energy Solutions for a Changing World

The Regulatory Assistance Project (RAP)®
Belgium · China · Germany · India · United States

50 State Street, Suite 3
Montpelier, Vermont 05602
USA

1 802-223-8199
info@raponline.org
raponline.org

Decarbonizing Transportation in Vermont

The Benefits and Costs of a Clean Transportation System in Vermont

MJB & A

February 13, 2019

Contents

Acknowledgements

Lead Authors: Dana Lowell, Brian Jones, and Alissa Huntington

This report, *Decarbonizing Transportation in Vermont*, explores and documents the costs and benefits of a suite of abatement strategies that could be used to significantly reduce greenhouse gas emissions from on-road transportation in Vermont. This analysis is based on MJB&A's independent report, *Decarbonizing Transportation*, released in October 2018, which focuses on the Northeast and Mid-Atlantic region. For this report, the total regional values were apportioned to Vermont based on Vermont's share of regional light duty vehicle and medium and heavy-duty vehicle miles traveled.

MJB&A would like to thank the Regulatory Assistance Project (RAP) for the funding that helped make this work possible. We would also like to thank David Farnsworth, Rich Cowart, and Rick Weston for their input and assistance.

This report is available at www.mjbradley.com.

About M.J. Bradley & Associates

M.J. Bradley & Associates, LLC (MJB&A), founded in 1994, is a strategic consulting firm focused on energy and environmental issues. The firm includes a multi-disciplinary team of experts with backgrounds in economics, law, engineering, and policy. The company works with private companies, public agencies, and non-profit organizations to understand and evaluate environmental regulations and policy, facilitate multi-stakeholder initiatives, shape business strategies, and deploy clean energy technologies.

For questions or comments, please contact:

Dana Lowell
Senior Vice President
M.J. Bradley & Associates, LLC
+1 978 369 5533
dlowell@mjbradley.com

Introduction

This analysis evaluates the costs and benefits of three major strategies aimed at significantly reducing emissions from on-road vehicles in Vermont in line with the state's 2050 commitments: (1) to reduce greenhouse gas (GHG) emissions 80 to 95 percent below 1990 levels, with an intermittent goal of at least a 40 percent reduction by 2030, and (2) source 90 percent of energy needs from renewable sources.[1] The transportation sector is the largest contributor to GHG emissions in Vermont, accounting for 47 percent of the state's GHG emissions. The three modeled strategies include significant electrification of both light-duty and medium- and heavy-duty vehicles, increased efficiency for the remaining new conventional vehicles, and greater use of bio-based renewable fuels in conventional vehicles.

The cumulative net investment required to implement the modeled abatement strategies - primarily incremental vehicle purchase costs and investments in electric vehicle (EV) charging infrastructure - is estimated to be $416 million[2] through 2030. However, these investments will yield significant fuel cost savings, as well as net revenue for electric utilities. Starting in 2031 annual *net* financial benefits (savings minus costs) turn positive – rising to $50 million in 2035, $120 million in 2040, and $170 million in 2050. By 2037, the total societal investment will be paid back via net fuel cost savings, and positive cumulative financial benefits will start to accrue rapidly. By 2050 cumulative financial net benefits will reach $1.66 billion in the state.

Based on this analysis, a per-gallon fee of $0.02/gallon[3] applied to all on-road gasoline and diesel fuel used in Vermont would raise sufficient revenue to cover the public investments required to put the state on a path toward significant electrification of the light-duty fleet. In order to jump-start and sustain efforts to electrify the medium- and heavy-duty truck fleet, additional investments would be required. To raise sufficient revenue to make significant efforts toward medium- and heavy-duty vehicle electrification a per-gallon fee of at least $0.16/gallon would be required.

Revenues generated from a per gallon fee could complement other state programs and incentives that are already supporting the transition to a low carbon transportation system in Vermont, including the Beneficiary Mitigation Plan for the Volkswagen Environmental Mitigation Trust.[4] For example, the revenue from a per gallon fee could be reinvested in the Vermont economy by targeting the following areas: EV purchase incentives (light-duty, medium- and heavy-duty including transit and school buses); EV charging infrastructure rebates and grants (residential, multi-unit dwellings, workplace, destination centers); and strategies to reduce vehicle miles traveled (VMT).

---

[1] 2016 Comprehensive Energy Plan (CEP) available at: https://outside.vermont.gov/sov/webservices/Shared%20Documents/2016CEP_Final.pdf

[2] Costs and benefits are presented in 2018$.

[3] This analysis assumes that the initial fee would be increased periodically in line with inflation.

[4] Vermont Beneficiary Mitigation Plan for the Volkswagen Environmental Mitigation Trust available at: https://dec.vermont.gov/sites/dec/files/aqc/mobilesources/documents/VW_Env_Mitigaiton_Trust_Final_BMP_29May2018.pdf

Methodology

The transportation sector strategies evaluated include: (1) increased fuel efficiency of new gasoline and diesel vehicles; (2) widespread vehicle electrification; and (3) decarbonizing traditional liquid transportation fuels. The analysis focuses on personal vehicles (cars and light trucks), medium- and heavy-duty single unit trucks, transit and school buses, and heavy-duty combination trucks (also known as tractor trailer trucks or semis).[5] This analysis only addresses on-road vehicles and does not consider air travel, non-road freight transport (rail, water, and pipeline), and other non-road vehicles (e.g., equipment for construction, warehouses, and agriculture.).[6]

The Baseline is a "business as usual" case with no change to current federal new vehicle fuel efficiency (Corporate Average Fuel Economy Standards [CAFE]) and GHG standards,[7] no policies designed to reduce the carbon intensity of traditional liquid fuels, and relatively low levels of vehicle electrification. The "80x50 Case" includes annual increases in new vehicle fuel efficiency beyond current standards, annual reductions in the carbon intensity of liquid transportation fuels, and significantly higher levels of EV penetration than in the Baseline scenario. Figure 1 provides the Baseline and 80x50 Case assumptions.

The 80x50 case did not include enhancements to public transportation or other approaches designed to slow the growth of, or reduce, personal VMT, or freight system enhancements or mode shifting to slow the growth of, or reduce, medium- and heavy-duty truck miles. Again, these strategies would offer further opportunities to reduce air pollution and GHG emissions from transportation but were beyond the scope of this study.

The costs associated with these abatement measures include higher vehicle purchase costs compared to "baseline" vehicles without these policies, the cost of necessary electric vehicle charging infrastructure, costs required to reduce the carbon intensity of liquid transportation fuels, and costs to supply additional electricity for electric vehicles.

The costs associated with the accelerated adoption of electric vehicles included the incremental costs required to supply a mix of renewable and natural gas-fired electricity for vehicle charging, including the costs of battery storage technology to integrate additional variable renewable energy resources (wind and solar).[8] The costs associated with reducing the carbon intensity of traditional transportation fuels

---

[5] This analysis is based on MJB&A's independent report, *Decarbonizing Transportation*, available at https://www.mjbradley.com/sites/default/files/UCS%20Final%20Report%20FINAL%2005oct18.pdf which explores the costs and benefits of a suite of abatement strategies that could be used to significantly reduce greenhouse gas emissions from on-road transportation within the Northeast and Mid-Atlantic region. The total regional values were apportioned to Vermont for this report based on Vermont's share of regional light duty vehicle, and medium and heavy-duty vehicle miles traveled.

[6] These segments of the transportation system offer further opportunities to reduce air pollution and GHG emissions but were beyond the scope of this study.

[7] In August 2018 the Department of Transportation and Environmental Protection Agency proposed flat-lining fuel efficiency and GHG emission standards at 2020 levels through 2026. As the fate of this proposal is still uncertain, for this analysis the baseline scenario includes current fuel efficiency and emission requirements through model year 2025, although these standards are likely to be less stringent than what is included in the baseline when the rule is finalized.

[8] In order to reflect the potential costs of integrating additional renewable energy capacity, MJB&A assumed that incremental renewable new builds would require energy storage capacity equal to 15 percent of the renewable

were modeled as incremental costs required to purchase the volume of renewable liquid fuels necessary to comply with the modeled carbon intensity targets.

Figure 1 Baseline and Abatement Scenario Assumptions

	Increased New Vehicle	Vehicle Electrification*	Decarbonized Fuels
Passenger cars and light trucks	**Baseline:** Current GHG emission standards through MY2025 **80x50 Case:** 5% annual increase MY2026-2030; 2% annual increase MY2031-2050	**Baseline:** <1% EV penetration **80x50 Case:** 90% by 2050	Lower carbon intensity for liquid fuels in the total transportation pool: **Baseline:** N/A **80x50 Case:** -3% (2020); -8% (2030); -16% (2050) Reductions are relative to 2010 carbon intensity
Single unit trucks	**Baseline:** Current GHG emission standards through MY2027 **80x50 Case:** 1.5% annual increase MY2028-2050	**Baseline:** <1% EV penetration **80x50 Case:** 70% by 2050	
Transit and school buses	**Baseline:** Current GHG emission standards through MY2027 **80x50 Case:** 1.5% annual increase MY2028-2050	**Baseline:** <1% EV penetration **80x50 Case:** 95% by 2050 (transit); 70% by 2050	
Combination trucks	**Baseline:** Current GHG emission standards through MY2027 **80x50 Case:** 1.5% annual increase MY2028-2050	**Baseline:** <1% EV penetration **80x50 Case:** 30% by 2050	

* EV penetration is the percentage of all in-use vehicles that are plug-in, both battery-electric and plug-in hybrid. The grid mix assumed to satisfy incremental demand for electricity includes a lower carbon grid mix in the 80x50 Case.

Cumulative financial benefits are the direct net financial benefits to consumers within Vermont that result from the modeled abatement strategies. These net financial benefits are primarily net fuel cost savings, after subtracting the costs of more expensive vehicles and charging infrastructure for EVs. The savings associated with lower EV maintenance (i.e., oil changes and tune-ups) costs are also factored in. This analysis modeled approximately 37,500 light duty plug in electric vehicles (PEVs) in 2020, 76,000 in 2025, 137,000 in 2030, 328,000 in 2040, and 500,000 in 2050. Note that total fleet growth is assumed to be more than14 percent between 2018 and 2050.

Cumulative financial benefits are negative in the short term – i.e. incremental annual vehicle and charging infrastructure costs are higher than annual net fuel costs savings through around 2030. This is primarily due to the investment required for electric vehicle charging infrastructure and the higher purchase price of electric vehicles compared to conventional vehicles[9]. However, over time the incremental cost of EVs is expected to fall and annual financial net benefits turn positive and expand

capacity added each year. While EVs have the potential to serve as sources of storage and reserve energy for the grid during periods of high demand, the role of EVs as a distributed energy resource is not considered in this analysis.

[9] The analysis indicates that the net benefits of more stringent fuel efficiency standards for conventional vehicles are positive every year, even in the near term; i.e. the annual fuel cost savings from more efficient vehicles are greater than the annual incremental vehicle costs to buy more efficient vehicles.

dramatically as the region benefits from net fuel cost savings and downward pressure on electricity rates due to net revenue from electricity used to charge EVs.[10]

For a detailed explanation of the analysis methodology, please refer to the full regional Northeast and Mid-Atlantic region analysis, *Decarbonizing Transportation*, on MJB&A's website.

Background – Vermont

Due to the state's rural character and small industrial base, the transportation sector accounts for nearly half of Vermont's GHG emissions and more than one-third of Vermont's energy consumption. According to the Census Bureau, Vermont is the second most rural state with 61.1 percent of residents residing in rural areas in 2010.[11] The state's rural settlement contributes to driving patterns: nationally, Vermont ranked eleventh in 2015 for per capita VMT at 11,680 compared to the national average of 9,630.[12] Vermont's total VMT hit 7.31 billion miles in 2015, the highest it had been since 2009. According to the 2016 Comprehensive Energy Plan (2016 CEP), although a flat or decreasing VMT trend will indicate plan success, current policies and low fuel prices could contribute to a rise in VMT through 2050.

Vermont's Low Emission Vehicle (LEV) program, authorized under section 177 of the Clean Air Act, has been in effect since 1996. These standards include a zero-emission vehicle (ZEV) mandate that requires auto manufacturers to sell increasing numbers of ZEVs each year between 2018 and 2025. Vermont is also a signatory to the 8-state ZEV Memorandum of Understanding (ZEV MOU), in which participating states pledge to enact policies that will ensure the deployment of 3.3 million ZEVs along with supporting charging infrastructure by 2025. The Vermont Department of Environmental Conservation estimates that by 2025, about 15 percent of new vehicles sold in Vermont will be required to be ZEVs to comply with the ZEV mandate.[13]

Accelerating the adoption of EVs is one of the most effective ways to reduce GHG emissions sufficiently to meet Vermont's quickly approaching 2025 goals. Recent analyses estimate that reaching the goal of 10 percent renewably powered transportation would require between 45,000 and 60,000 EVs by 2025. As of July 2018, there were only 2,612 passenger EVs registered in the state, out of nearly 450,000 total light duty vehicle registrations.[14]

---

[10] This study estimated the economic benefits that would accrue to all electric utility customers in the study region due to increased utility net revenue (revenue minus costs) from electric vehicle charging. This revenue could be used to support operation and maintenance of the electrical grid, thus reducing the need for future electricity rate increases. In general, a utility's costs to maintain their distribution infrastructure increase each year with inflation, and these costs are passed on to utility customers in accordance with rules established by the state's Public Utilities Commission (PUC), via periodic increases in residential and commercial electric rates. However, under PUC rules and procedures the majority of projected utility net revenue from increased electricity sales for electric vehicle charging would in fact be passed on to utility customers, not retained by the utility companies. In effect this net revenue would put downward pressure on future rates, delaying or reducing future rate increases, thereby reducing customer bills.

[11] Available at: https://www.census.gov/newsroom/releases/archives/2010_census/cb12-50.html

[12] 2010 Census: https://www.census.gov/prod/cen2010/cph-2-47.pdf

[13] Accessed January 9, 2019 at: https://dec.vermont.gov/air-quality/mobile-sources/lev/zev

[14] Drive Electric Vermont. Total registration are for 2016, the latest data available.https://www.driveelectricvt.com/Media/Default/docs/maps/Vermont_EV_Registration_Trends_July_2018.pdf ; FHWA 2016 https://www.fhwa.dot.gov/policyinformation/statistics/2016/mv1.cfm

On July 20, 2017, Governor Phil Scott issued Executive Order 12-17 establishing the Vermont Climate Action Commission (VCAC). The Executive Order charged the Commission to "develop a strategy to reduce greenhouse gas emissions and combat climate change that addresses these fundamental principles:

- solutions that reduce GHG emissions must spur economic activity, inspire and grow Vermont businesses, and put Vermonters on a path to affordability;
- the development of solutions must engage all Vermonters, so no individual or group of Vermonters is unduly burdened; and
- programs developed to reduce GHG emissions must collectively provide solutions for all Vermonters to reduce their carbon impact and save money." [15]

The VCAC released its *Report to the Governor* on July 31, 2018, providing a host of recommendations that are "intended to both mitigate Vermont's contribution to climate change and seize the economic opportunity in a smart, strategic and equitable response."[16] Through the *Report to the Governor*, VCAC outlined suggestions for reducing emissions in transportation, building energy, and land use, expanding upon 17 recommendations to support light-duty and medium- and heavy-duty vehicle electrification as well as transport mode shifting.

The 2016 CEP outlines three specific goals for the transportation sector as well as a host of options to support the transition.[17] The three goals included: 1) reduce total transportation energy use by 20 percent from 2015 levels by 2025; 2) increase the share of renewable energy in all transportation to 10 percent by 2025 and 80 percent by 2050; and 3) reduce transportation-emitted GHGs by 30 percent from 1990 levels by 2025.

Several Vermont electric utilities have already begun encouraging cleaner transportation options. For instance, Vermont's utilities and cooperatives such as Green Mountain Power (GMP), Burlington Electric Department (BED), Stowe Electric Department, Vermont Electric Cooperative, and Washington Electric Cooperative offer a range of incentives to go electric: low-income incentives between $600 and $1,900, vehicle specific rebates for the Nissan Leaf and Chevy Bolt and Volt, special charging rates, and free in-home L2 chargers.[18]

Four primary state agencies have led the push for electrification: the Agency of Natural Resources (ANR) (responsible for administering the VW Fund), the Department of Public Service (PSD), and the Agency of Commerce and Community Development (ACCD) (responsible for the EVSE component of the VW Fund), the Agency of Transportation (VTrans). These and other agencies offer a range of incentives to EV owners

[15] EO 12-17 https://governor.vermont.gov/sites/scott/files/documents/EO%2012-17%20-%20Climate%20Action%20Commission.pdf

[16] Vermont Climate Action Commission: Executive Order No. 12-17 Report to the Governor, July 31, 2018 https://anr.vermont.gov/sites/anr/files/Final%20VCAC%20Report.pdf

[17] For progress report on these goals, see The Vermont Transportation Energy Profile 2017, p. ii https://vtrans.vermont.gov/sites/aot/files/planning/documents/planning/The%20Vermont%20Tranportation%20Energy%20Profile_2017.pdf

[18] For more information on utility incentives, see Drive Electric Vermont's Purchase Incentives site https://www.driveelectricvt.com/buying-guide/purchase-incentives.

in addition to utility programs. Additionally, EVs are exempt from state emissions testing and have registration fees that are nearly half the cost of gas- or diesel-powered vehicles. [19]

The Vermont Public Utilities Commission opened an investigation on July 9, 2018, to identify and eliminate barriers to the widespread adoption of electric vehicles, which was initiated in response to Act 158 of the 2017-2018 legislative session. A report will be filed with the Vermont Legislature by July 1, 2019, setting forth the Commission's analysis of the barriers to EV adoption in Vermont and recommendations on how to reduce or eliminate them.

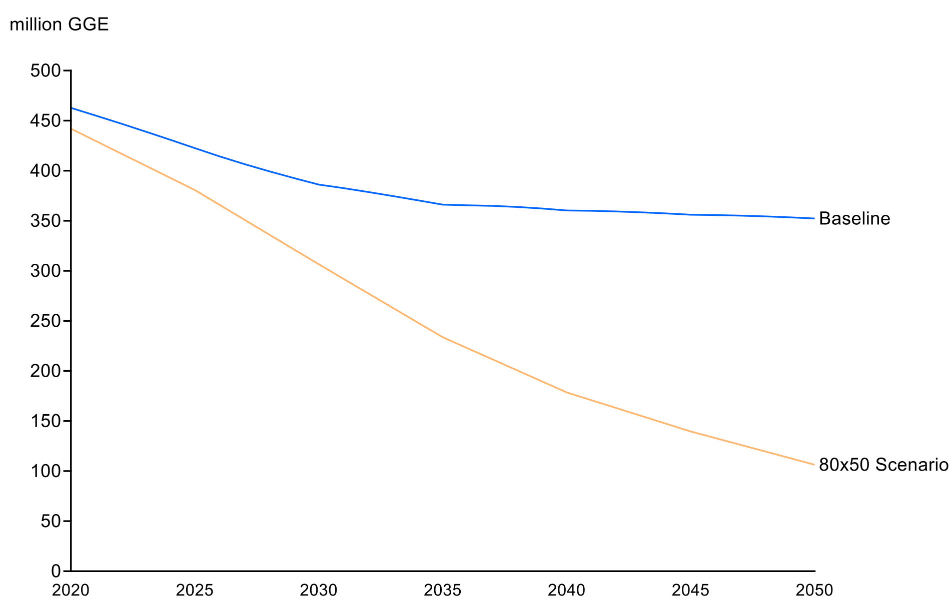
As noted above, the three most important strategies to reduce transportation emissions in Vermont are transportation electrification, increasing vehicle fuel efficiency, and doubling rideshare and vanpool utilization. The abatement measures considered in this analysis –electrification, fuel efficiency, and low carbon fuels – do not incorporate all these strategies but aims to encompass some of the measures Vermont is considering to reduce GHG emission from the transportation sector. The next section provides the results of the modeling.

[19] For more information on "green driver incentives" see the Department of Motor Vehicles site https://www.dmv.org/vt-vermont/green-driver-state-incentives.php.

Summary of Results

This section provides a summary of the modeling results of the three major strategies aimed at significantly reducing emissions from on-road vehicles in Vermont: electrification of both light-duty and medium- and heavy-duty vehicles, increased efficiency for the remaining new conventional vehicles, and greater use of bio-based renewable fuels in conventional vehicles. The major benefits of these abatement measures include significant reductions in gasoline and diesel fuel use and resulting reductions in net GHG emissions, as well as reductions in net emissions of nitrogen oxides (NOx) and particulate matter ($PM_{2.5}$). The modeled reductions in gasoline and diesel use also produce significant reductions in net fuel costs, as well as higher net revenue for electric utilities, which can be used to maintain existing infrastructure and put downward pressure on future electricity rates.

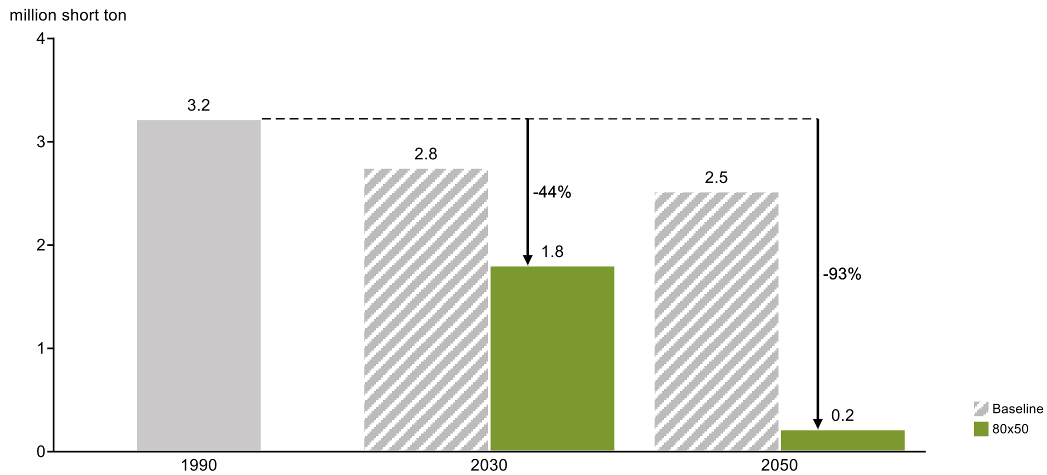
Figure 2 Projected Fuel Use Reduction in Vermont



The suite of modeled strategies reduces on-road transportation sector emissions in Vermont by 44 percent below 1990 levels in 2030 and 93 percent below 1990 levels in 2050 as shown in Figure 3.[20] The Baseline Scenario projects a modest decline in emissions due to the existing federal fuel efficiency and GHG emission standards. Relative to the Baseline Scenario, cumulative GHG emission reductions total approximately 6.1 million metric tons (MT) by 2030, approximately 19 MT by 2040 and approximately 40 MT by 2050.

[20] Current policies are estimated to contribute 23 percent of the emission reductions by 2050. This chart only includes emissions from on-road vehicles. To achieve an 80 percent reduction in emissions from the entire transportation sector, other strategies would need to be employed to reduce emissions from non-road equipment.

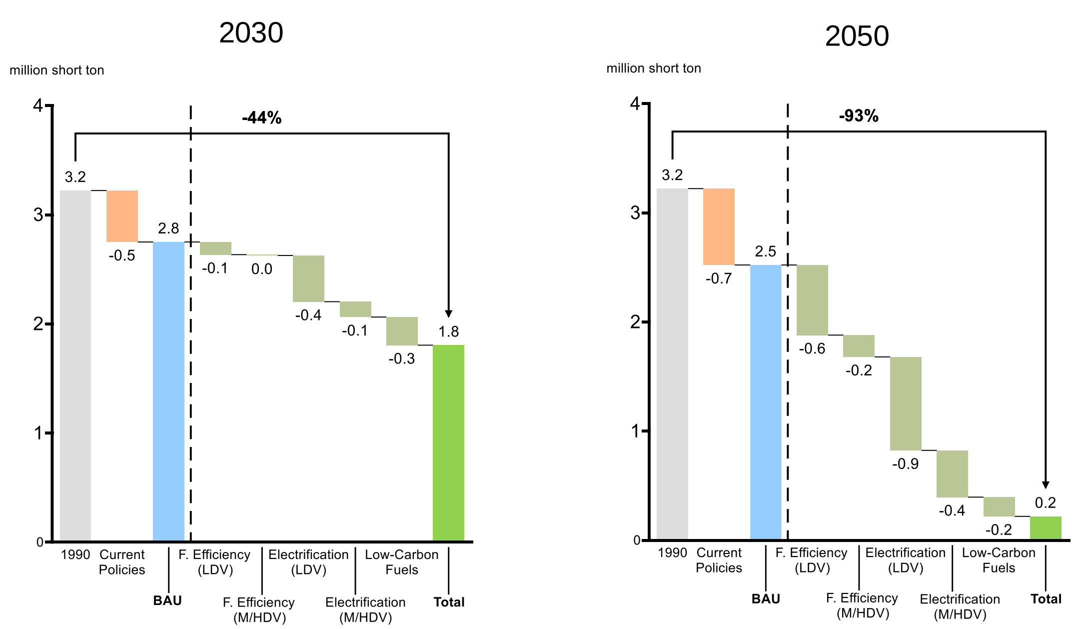
Figure 3 Effective* Transportation Sector CO_2 Emissions in Vermont



*Direct transportation sector emissions + electrification related emissions from electric sector. Excluding aviation fuel and RFO.

As highlighted in Figure 4, light-duty vehicle electrification is responsible for 29 percent of the emissions reductions by 2050. Increased fuel efficiency for new light-duty vehicles contributes 21 percent, and medium- and heavy-duty vehicle electrification contributes 14 percent. Medium- and heavy-duty fuel efficiency improvements and reduced carbon intensity of liquid fuels each contribute six percent of the modeled emissions reductions.

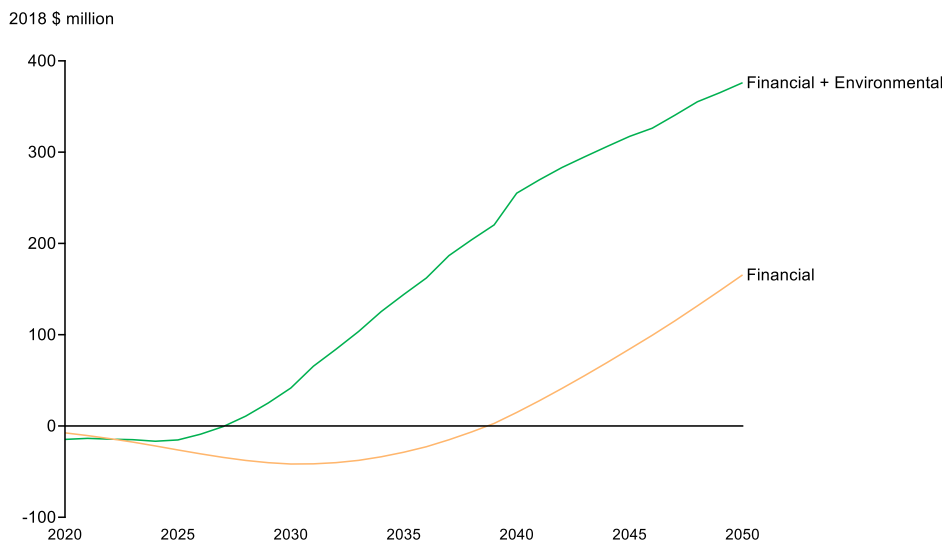
Figure 4 CO_2 Emission Reduction by Strategy in Vermont (million tons)



The estimated cumulative net benefits (benefits minus costs) of the 80x50 scenario, compared to the baseline scenario, are shown in Figure 5. Cumulative financial benefits are the direct net financial benefits to Vermont consumers. These net financial benefits primarily consist of net fuel cost savings - after subtracting the costs of more expensive vehicles, the cost of charging infrastructure for EVs, and the incremental cost of low- carbon liquid fuels. Cumulative environmental benefits are the monetized net emission reductions benefits GHG, NOx and $PM_{2.5}$ associated with the reduction of gasoline and diesel related emissions after subtracting emissions associated with electricity generation.

Cumulative financial benefits are negative in the short term – i.e. incremental annual vehicle and charging infrastructure costs are higher than annual net fuel costs savings through around 2030. This is primarily due to the investment required for electric vehicle charging infrastructure and the higher purchase price of electric vehicles compared to conventional vehicles.[21] However, over time the incremental cost of EVs is expected to fall and annual financial net benefits turn positive and expand dramatically as Vermont benefits from net fuel cost savings and downward pressure on electricity rates due to net revenue from electricity used to charge EVs.

Figure 5 Cumulative Net Benefits of 80x50 Scenario in Vermont



Under the 80x50 scenario, the cumulative net societal investment required to implement the modeled abatement strategies is estimated to be $416 million[22] through 2030. Starting in 2031 annual net financial benefits turn positive – rising to $50 million in 2035, $120 million in 2040, and $170 million in 2050. By 2037, the total societal investment will be paid back via net fuel cost savings, and positive

[21] The analysis indicates that the net benefits of more stringent fuel efficiency standards for conventional vehicles are positive every year, even in the near term; i.e. the annual fuel cost savings from more efficient vehicles are greater than the annual incremental vehicle costs to buy more efficient vehicles.
[22] Costs and benefits are presented in 2018$.

cumulative financial benefits will start to accrue rapidly. By 2050 cumulative financial net benefits will reach $1.66 billion.

For this study the authors used values for the "Social Cost of CO_2" ($/MT) which were developed by the U.S. government's Interagency Working Group on Social Cost of Greenhouse Gases. The social cost estimates are based on average modeling results using 2.5, 3 and 5 percent discount rates, as well as 95th percentile results using a 3 percent discount rate. For this study the authors used the average values resulting from a 3 percent discount rate- $40/MT in 2018, rising to $80/MT in 2050.[23] To estimate net NOx and $PM_{2.5}$ reductions from vehicle electrification, this study estimated the reduction in emissions due to reducing miles driven by conventional vehicles, then subtracted the emissions resulting from generation of the electricity required to charge the electric vehicles that replaced them. The monetized value of the estimated NOx and $PM_{2.5}$ reductions was calculated using avoided emission damage estimates ($/MT) developed by EPA.[24] The estimated cumulative emission reductions and monetized benefits are shown in Table 1 below.

Table 1 Cumulative Environmental Benefits of 80x50 Scenario in Vermont

	2030	2040	2050
GHG Benefits			
Emission Reduction (Million MT)	6.1	19.3	39.1
Monetized Benefits (2018 $ Billions)	0.3	1.2	2.6
NOx Benefits			
Emission Reduction (1,000 ton)	1.3	5.0	12.3
Monetized Benefits (2018 $ Billions)	0.02	0.08	0.2
$PM_{2.5}$ Benefits			
Emission Reduction (1,000 ton)	0.03	0.13	0.3
Monetized Benefits (2018 $ Billions)	0.03	0.10	0.24

[23] Interagency Working Group on the Social Cost of Greenhouse Gases, Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (May 2013, Revised July 2015).
[24] U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Air Quality Planning and Standards, Technical Support Document, Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors, February 2018.

Incentivizing Transportation Electrification

This section addresses the public investments likely to be required to put Vermont on a path toward high levels of vehicle electrification. For this analysis the authors used the results of the 80x50 modeling (discussed above) but focused specifically on net benefits to electric vehicle owners. To estimate the level of public investment required, the authors assumed that most consumers would not purchase EVs unless they were at least cost-equivalent to conventional vehicles.[25] To incentivize additional EV purchases (equivalent to the levels modeled in the 80x50 scenario) public investments could, for example, be directed to subsidizing public charging infrastructure, or to providing EV purchase incentives. These types of public investments would reduce the cost of owning EVs, making them more cost competitive with conventional vehicles and more attractive to consumers.

To fund the necessary public investments in transportation electrification new source(s) of revenue will be required. One method to raise this revenue would be to assess a per-gallon fee on transportation fuels sold in the state – primarily gasoline and diesel fuel. Using the 80x50 scenario this analysis also estimates the scale of fee that would be required to provide the necessary revenue for different levels of public investment in transportation electrification. Table 2 summarizes the results of the analysis.

The modeling shows that light-duty electric vehicles in Vermont could, on average, be cost competitive with conventional vehicles by about 2030.[26] In order to get onto this path, however, public investments of approximately $70 million will be required over the next ten years. These investments will yield 4.4 million metric tons of GHG reduction through 2030; as such, the required public investment through 2030 would be approximately $16 per metric ton of GHG avoided. After 2030, the required public investments in light-duty electrification would be only another $3 million, but total GHG reductions would total 25.1 million MT through 2050. Through 2050, therefore, the required public investment in light-duty vehicle electrification could be as low as $3/MT of GHG reduced.

The 80x50 modeling indicates that the economics of medium- and heavy-duty vehicles are more challenging. To reach at least cost parity with conventional vehicles medium- and heavy-duty electric vehicles will likely require higher levels of public investment than light-duty vehicles in the short term, and continuing investments over a longer period. As shown in Table 2, to incentivize the level of medium- and heavy-duty electrification included in the 80x50 scenario, over $560 million in public investment may be required through 2030, and over $2.9 billion may be required through 2050 (this assumes that fleets will not electrify if they can't save money compared to continued use of conventional vehicles). Through 2050 this level of medium- and heavy-duty electrification would yield an additional 9.2 million MT of GHG reduction; as such, the public investment required to achieve high levels of medium- and heavy-duty electrification could be as high as $315/MT of avoided GHG through 2050.

As shown in Table 2, the revenue required to fund public investments necessary to incentivize high levels of transportation electrification could range from $70 million (LDV only) to $560 million (LDV, and

[25] For this analysis, cost equivalence is on a total cost of ownership basis, including vehicle purchase, maintenance, and fuel costs over the full life of a vehicle.

[26] This assumes that in addition to direct fuel and maintenance cost savings, EV owners will receive 50 percent of the utility net revenue that results from electricity sales for EV charging. In recognition of the grid benefits that EVs provide, these net revenues could be returned directly to EV owners via utility investments in public charging infrastructure and/or via EV specific rates to incentivize EV charging load management.

M/HDV) through 2030, and from $73 million to $3.0 billion through 2050. Under the 80x50 scenario, if high levels of vehicle electrification are achieved, annual gasoline use in Vermont is projected to fall from 341 million gallons today to 61 million gallons in 2050. Similarly, annual diesel use is projected to fall from 122 million gallons today to 41 million gallons in 2050.

Table 2 Estimated Public Investment Required to Incentivize Transportation Electrification

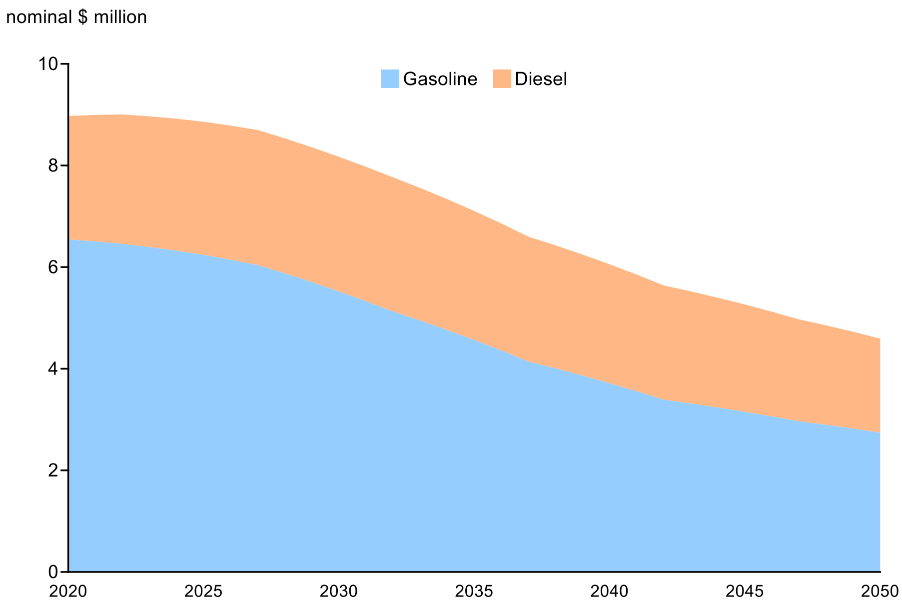
	Through 2030			Through 2050		
	Public Investment (2018 $ million)	GHG Reduction (Mill MT)	Cost Per Ton Reduced (2018$/MT)	Public Investment (2018$ million)	GHG Reduction (Mill MT)	Cost Per Ton Reduced (2018$/MT)
Light Duty Electric Vehicles	$70	4.4	$16	$73	25.1	$3
Medium-and Heavy-Duty Electric Vehicles	$564	1.0	$560	$2,905	9.2	$315
TOTAL	**$634**	**5.4**	**$117**	**$2,978**	**34.3**	**$87**

See Figure 6 for an estimate of the annual revenue that could be generated by a $0.02/gallon fee[27] assessed on all on-road gasoline and diesel fuel sold in Vermont, if the 80x50 scenario is achieved. As shown, such a fee could raise approximately $8.9 million in 2020, but annual revenues would decline year-over-year as diesel and gasoline use are replaced by electricity, falling to $8.2 million in 2030, $6 million in 2040, and $4.6 million in 2050. Cumulative revenue through 2050 would total $218 million, or $157 million in constant 2018 dollars. The revenue from a $0.02/gallon fee (indexed to inflation) would be more than enough to fund the public investments required to incentivize high levels of light duty electrification in Vermont.

To also fund investments necessary to incentivize medium- and heavy-duty vehicle electrification in Vermont a higher per-gallon fee would be required. For example, a $0.15/gallon fee could generate $600 million through 2030 and $1.2 billion through 2050 (2018$) – enough to fully fund light-duty electrification investments, to fully fund medium- and heavy-duty investments through 2030, and to continue to partially fund medium- and heavy-duty investments between 2030 and 2050. To fully fund all medium- and heavy-duty electrification investments through 2050, fees approaching $0.38/gallon could be required.

[27] First assessed in 2020 at a level of $0.02/gallon, the fee is assumed to increase periodically at the rate of inflation, to maintain a constant fee level in current dollars.

Figure 6 Projected Annual Revenue from $0.02/gallon Fee Indexed to Inflation



*$0.02/gallon carbon fee applied to all on-road gasoline and diesel fuel in 2020. Per gallon fee increases each year at rate of inflation

Revenue Investment Options

The revenue from a per gallon fee could be invested in programs and incentives that are modeled in this analysis that would accelerate the transition to low carbon transportation in Vermont. In many cases, additional revenue could contribute to increasing Vermont's programs that are already in place.

Table 3 below summarizes key financial incentive and subsidy areas and offers examples of programs in Vermont and other states and utilities.[28] The table addresses four segments: transportation electrification, EV charging infrastructure, education, and other targeted programs.

Reducing the upfront cost of EV ownership will be essential, especially for rural Vermonters. One study found that when rating top transportation issues, urban respondents outweighed rural respondents on all issues but one – rural respondents' top concern was the price of travel.[29] Rural households spend seven percent more of their household budgets on transportation, meaning education campaigns that underscore the lower operation and maintenance and fuel costs of EVs will be vital.[30] In addition to personal EVs, electrified buses will not only benefit the communities that rely on public transit or school buses but also will reduce overall personal VMT.

---

[28] For more information on California's allocation of Cap-and-Trade revenue, see the 2018 Annual Report https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/2018_cci_annual_report.pdf or "Appropriations & Funded Programs" https://ww2.arb.ca.gov/our-work/programs/california-climate-investments/cci-funded-programs#Transportation. For more information on RGGI and "The Investment of RGGI Proceeds in 2016" (published September 2018), see https://www.rggi.org/sites/default/files/Uploads/Proceeds/RGGI_Proceeds_Report_2016.pdf. Vermont specific plans are on pages 39-41.

[29] Issues where urban respondents responded in higher rates than rural issues included: availability of public transportation, aggressive and distracted drivers, lack of walkways, traffic congestion, and safety concerns. https://www.apta.com/resources/reportsandpublications/Documents/APTA-Rural-Transit-2017.pdf

[30] https://www.apta.com/resources/reportsandpublications/Documents/APTA-Rural-Transit-2017.pdf

Table 3	Options for Investment of Revenue	
Segment	**Investment Options**	**Select Examples**
Transportation Electrification		
Passenger cars and light trucks	• Cash rebates (point of sale, or after purchase or lease of a new vehicle). ○ Incentives can be based on the size of the battery, vehicle range, and costs of the vehicle ○ Higher incentives could be provided based on income level • Dealership EV sales bonuses/incentives • Tax credits for new vehicle purchases • Excise tax credits • Low and zero interest car loans based on income level	• Several Vermont utilities offer rebates and collaborate with credit unions to offer low- and no-interest loans[31] • Three states RGGI states invest allowance auction revenue in EV incentive programs: 1. Delaware's Clean Transportation Rebate Program 2. Massachusetts' MOR-EV (mail rebate) 3. New York's Charge NY (point of sale) • Maryland provides an excise titling tax credit of $100/kWh of battery capacity up to $3,000 for the purchase or lease of EVs whose purchase price does not exceed $60,000
Medium and Heavy-Duty	• Transit bus grants and pilot programs • School bus grants and pilot programs • Delivery truck grants and pilot programs • Fleet electrification advisory services for municipal and commercial entities	• VT ANR is reviewing proposals for a $2 million electric bus pilot program • California's Rural School Bus Pilot Project[32] or Zero-Emission Truck and Bus Pilot Projects[33] are funded by Cap-and-Trade revenue
EV Charging Infrastructure		
Residential	• Incentives for electric service upgrades and EVSE installation costs at single family homes • Free Level 2 (L2) chargers	• GMP offers a free L2 charger with the purchase of a *new* electric vehicle

[31] Burlington Electric Department EV Rebate Program is available at: https://www.burlingtonelectric.com/ev#financing
[32] https://www.schoolbusfleet.com/news/719955/california-pilot-project-pushes-alt-fuel-school-buses
[33] https://www.arb.ca.gov/msprog/aqip/solicitations.htm

Segment	Investment Options	Select Examples
Multi-Unit Dwellings (MUD)	• Incentives for electrical service upgrades and EVSE installation costs • Free L2 chargers	• Massachusetts's EVIP has MUD charger incentives
Workplace	• Provide L2 or DCFC charger incentives • Link solar PV, storage, and EVSE programs to help offset increased electrical load	• Drive Electric Vermont (DEV) Drive the Dream Vermont 2015 program, recognizing employer commitments to expand EV use[34] • Massachusetts's Electric Vehicle Incentive Program (EVIP) has workplace charger incentives, providing 60% of hardware costs[35] • California linked EVSEs to GM's solar tracking tree[36]
Public Charging	• Identify key charging hubs in Vermont to invest in EVSE (i.e. ski resorts, shopping centers, grocery stores, parking garages) • Incentives for L1 and L2 EVSE at publicly-owned parking lots • Incentivize deployment of L1 and L2, and DCFC at airports, train stations and transit centers	• Vermont's EVSE Grant Program funded by VW funds • Vermont Energy Investment Corporation (VEIC) completed an analysis on DCFC charging on highway corridors, including viable options at shopping centers and Park and Rides[37] • Duke Energy's "Park & Plug" pilot program offers free DCFCs through 2022 for high traffic or major corridors[38] • New York is investing $250 million for 200 fast chargers on roadways and in cities, along with 400 public charging stations at parking lots, airports, and train stations through the EVovle NY program [39]
Transit and school buses	• Grant programs and rebates for bus on route and in depot charging • State tax credits for EVSE	• VEIC supports electric school bus technology, outlining the second step in integration as securing funding[40] • Chicago CTA will purchase buses with on route charging[41]

34 https://www.driveelectricvt.com/blog/drive-the-dream-vermont-launches
35 https://www.mass.gov/how-to/apply-for-massevip-workplace-charging-incentives
36 https://www.driveclean.ca.gov/pev/calstart_wpc_incentives.pdf
37 https://vtrans.vermont.gov/sites/aot/files/planning/documents/DC%20Highway%20Corridor%20Report_112217_Final_FULLVERSION-web.pdf
38 https://www.duke-energy.com/our-company/florida-future/park-and-plug
39 https://www.governor.ny.gov/news/governor-cuomo-announces-250-million-initiative-expand-electric-vehicle-infrastructure-across
40 https://www.veic.org/Media/success-stories/electric-school-bus-intro.pdf
41 https://chi.streetsblog.org/2017/12/01/cta-plans-to-purchase-20-electric-buses-with-en-route-chargers-next-year/

Segment	Investment Options	Select Examples
		• Proterra offers three charging solutions that include depot and on route charging[42]
Education		
State campaigns	• Expand education and outreach opportunities and platforms • Set targeted state, city, town or college/university adoption targets that can bringing local agencies and entities together to encourage EV adoption • Partner with dealerships for Ride and Drive Events: National Drive Electric Week or feature EVs in parades	• DEV • DEV hosted a test ride event for National Drive Electric Week 2015 with food and opportunities to ride in an EV[43] • Solarize Mass (state)[44] and the Concord Solar Challenge (town) [45] set goals in Massachusetts for residential PV installations with NGO/business partnerships
Targeted Programs for Income-Eligible Vermonters		
Low Income and Disadvantaged Communities	• Incentives for car sharing pilots and programs • Incentives for car scrap and replace programs • Vehicle financing – low and zero interest loans • Incentives for used EV market • Improve access to electrified public transit and other mobility solutions like E-Bikes • Discounted public transit passes • Income tax rebates	• Many of Vermont's utility EV rebate programs offer additional rebates only for low-to-moderate income households[46] • DEV compiled a table of used EV prices[47] • Statewide nonprofits like VBike and Local Motion[48] • Sacramento and Los Angeles, California: pilot programs give low-income seniors free access to eight Zipcar Kia Soul EVs • Xcel Energy partnered with car-sharing nonprofit HourCar

42 https://www.proterra.com/technology/chargers/
43 https://www.driveelectricvt.com/blog/electric-car-demo-day-at-vermont-teddy-bear
44 https://www.masscec.com/solar/solarize-mass
45 https://www.northamericansolarstores.com/SolarNews/regional-solar/concord-solar-challenge/
46 Green Mountain Power's Low Income Rebate is available at: https://greenmountainpower.com/product/ev-rebate/
47 https://www.driveelectricvt.com/blog/affordable-used-electric-cars-arrive-in-vermont
48 https://www.driveelectricvt.com/ebikes

Appendix A: Annual Net Benefits

The projected annual costs, benefits, and net benefits from the modeled abatement scenarios (relative to the baseline scenario) are shown in Table B-1.

			ANNUAL IN					
2018 $ billions			**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Incremental Vehicle Costs	**Vehicle Efficiency**	LDV (CAFE+)	$0.00	($0.01)	($0.02)	($0.03)	($0.04)	($0.03)
		M/HDV (EPA Phase 3)	$0.00	($0.00)	($0.00)	($0.01)	($0.02)	($0.03)
	Transportation Electrification	LDV	($0.04)	($0.05)	($0.04)	($0.03)	($0.02)	($0.00)
		M/HDV	($0.03)	($0.04)	($0.06)	($0.09)	($0.10)	($0.12)
PEV Charging Infrastructure		LDV - home chargers	($0.01)	($0.01)	($0.03)	($0.04)	($0.05)	($0.06)
		LDV - Public Chargers	($0.01)	($0.02)	($0.03)	($0.03)	($0.04)	($0.04)
		M/HDV	($0.01)	($0.02)	($0.03)	($0.04)	($0.05)	($0.06)
Incremental Electricity Cost		LDV	($0.06)	($0.10)	($0.17)	($0.24)	($0.29)	($0.34)
		M/HDV	($0.02)	($0.03)	($0.05)	($0.07)	($0.09)	($0.11)
Low Carbon Fuel Standard			($0.02)	($0.03)	($0.03)	($0.03)	($0.02)	($0.02)
Low Carbon Grid			$0.00	$0.00	$0.00	$0.01	$0.01	$0.02
Sub-total Costs			**($0.20)**	**($0.31)**	**($0.45)**	**($0.59)**	**($0.70)**	**($0.79)**
Gasoline Savings			$0.11	$0.21	$0.34	$0.48	$0.56	$0.62
Diesel Fuel Savings			$0.02	$0.05	$0.10	$0.15	$0.20	$0.25
Utility Net Revenue from PEV Charging		LDV	$0.02	$0.03	$0.05	$0.06	$0.07	$0.07
		M/HDV	$0.01	$0.01	$0.01	$0.02	$0.02	$0.02
Sub-total Financial Savings			**$0.15**	**$0.30**	**$0.50**	**$0.71**	**$0.85**	**$0.97**
NET FINANCIAL BENEFITS			**($0.04)**	**($0.01)**	**$0.05**	**$0.12**	**$0.15**	**$0.17**
Monetized GHG Benefits (3% AVG)			$0.03	$0.05	$0.08	$0.12	$0.14	$0.17
Monetized NOx Benefits (AVG)			$0.00	$0.00	$0.01	$0.01	$0.01	$0.01
Monetized PM2.5 Benefits (AVG)			$0.00	$0.00	$0.01	$0.01	$0.01	$0.02
NET FINANCIAL + ENVIRONMENTAL BENEFITS			**($0.02)**	**$0.04**	**$0.14**	**$0.26**	**$0.32**	**$0.38**
GHG Reduction	LDV	Million MT	0.4	0.7	1.0	1.2	1.4	1.5
	MHDV	Million MT	0.1	0.2	0.3	0.4	0.6	0.7
	TOTAL		0.5	0.9	1.3	1.7	2.0	2.2
NOx Reduction	LDV	1000 ton	0.0	0.1	0.1	0.2	0.2	0.3
	MHDV	1000 ton	0.1	0.1	0.2	0.3	0.5	0.7
	TOTAL		0.1	0.2	0.4	0.5	0.7	0.9
$PM_{2.5}$ Reduction	LDV	1000 ton	0.0	0.0	0.0	0.0	0.0	0.0
	MHDV	1000 ton	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL		0.0	0.0	0.0	0.0	0.0	0.0
Gasoline Savings	TOTAL	Million gallons	34.8	64.5	102.4	136.5	156.9	173.2
Diesel Savings	TOTAL	Million gallons	6.4	13.7	27.2	40.8	53.8	65.7

ENERGY FUTURES GROUP

energyfuturesgroup.com

Reducing CO_2 Emissions from Vermont Buildings

Potential and Cost-Effectiveness of Select Program Options

Prepared by:

Chris Neme, Energy Futures Group

Richard Faesy, Energy Futures Group

February 13, 2019

Energy Futures Group, Inc

PO Box 587, Hinesburg, VT 05461 – USA | 802-482-5001 | 802-329-2143 | info@energyfuturesgroup.com

Contents

About the Authors

Energy Futures Group (EFG) is a clean energy consulting firm based in Hinesburg, Vermont and with offices in Boston and New York. EFG specializes in the design, implementation and evaluation of programs and policies to promote investments in energy efficiency, renewable energy, other distributed resources and strategic electrification. EFG staff have worked on these issues on behalf of energy regulators, other government agencies, utilities and advocacy organizations across the United States, Canada, Europe, and China.

Chris Neme is a Principal and Co-Founder of EFG. He has extensive experience in the analysis of markets and development of policies to promote energy efficiency, demand response, and strategic electrification. His work regularly includes assessing forecasts of energy efficiency potential, the robustness of energy efficiency and other clean energy goals, the structure of utility shareholder incentives for meeting those goals, the design of efficiency and demand response programs, frameworks for assessing the cost-effectiveness of energy efficiency and other distributed resources, the potential for non-wires alternatives to cost-effectively defer traditional transmission and distribution system investments, the bidding of efficiency and other distributed resources into capacity markets, and other related issues. Prior to co-founding EFG in 2010, Chris managed the 30-person Consulting Division of the Vermont Energy Investment Corporation (VEIC); he also served on VEIC's Senior Management team and the Management Team for *Efficiency Vermont* (VEIC's largest project). During his more than 30 years in the industry, Chris has worked for clients in more than 30 states, four Canadian provinces and several countries in Europe. That has included defending expert witness testimony in more than 50 dockets before energy regulators in a dozen different states and provinces, as well as testimony before several state legislatures.

Richard Faesy is also a Principal and Co-Founder of EFG.   He specializes in residential buildings, technologies and markets, with expertise in both new construction and retrofits of existing homes, energy rating and labeling, building codes, financing, green building, strategic electrification, the integration of renewables and energy efficiency, and effective energy efficiency program design and implementation. Richard is a Certified Energy Rater, LEED Accredited Professional, and DOE Home Energy Score Assessor. He was founding member of the Residential Energy Services Network (RESNET) and the Northeast Home Energy Rating Systems (HERS) Alliance, the standards-setting organizations nationally and regionally for energy efficient residential new construction. During his more than 30 years in the industry, Richard has worked for clients in a dozen different states and provinces, as well as on a variety of national projects for clients such as the U.S. Department of Energy, the U.S. Environmental Protection Agency's Energy Star program, the U.S. Green Building Council, and the Energy Foundation.

Introduction

The Vermont Legislature has been considering adoption of some form of carbon pricing (e.g., a carbon tax or cap-and-trade regime) as a policy instrument for the state to begin to address its contribution to global climate change. The Legislature recently commissioned a report by Resources for the Future to analyze the effects that a carbon tax would have on the state's emissions of greenhouse gases. That report focuses on the effects of a carbon price – that is, how much a tax or an emission permitting program would reduce emissions of carbon dioxide as a result of making consumption of fuels that produce the greenhouse gas more expensive.

The Regulatory Assistance Project (RAP) commissioned Energy Futures Group (EFG) to examine the reductions in carbon dioxide that could be obtained – and the costs and cost-effectiveness of obtaining them – by directly funding programs or initiatives designed to help Vermonters invest in efficiency measures, electrification measures and/or renewable energy measures in their homes and/or businesses.[1] The source of such funding is not addressed in or relevant to this analysis, but one option would be to consider using a portion of carbon pricing revenue. The analysis was constrained by both budgetary and time limitations, so it is not intended to be either comprehensive or definitive. Instead, it provides an initial estimate of potential impacts for a select group of five different building measures. This report documents the results of our analysis of those measures.

Approach

Overview

The project was organized around the following tasks:

1. Developing a list of potential "measures" that could reduce carbon dioxide (CO_2) emissions from Vermont buildings.
2. Selecting a subset of those measures to analyze.
3. Characterizing the typical measure costs, impacts on fuel consumption, the useful life of each measure, and the carbon emissions reductions each measure would produce over its useful life.
4. Estimating how many of the measures a reasonably aggressive program could cause to be installed over the next decade, as well as the costs of running such programs.
5. Analyzing the cost-effectiveness of each measure and program, including the levelized cost per metric ton of CO_2 emissions reduction.

What follows is a brief discussion of our approach to each of these steps.

[1] The focus of this analysis is exclusively on measures and programs for reducing carbon emissions from buildings. A separate companion analysis that examines opportunities for reducing emissions from the transportation sector was conducted by MJ Bradley.

Potential Measure List

EFG relied principally on our own expertise, our understanding of the measures being targeted by Vermont's utilities as part of their plans to meet the state's Renewable Portfolio Standards Tier III requirements to help their customers reduce direct consumption of fossil fuels, and input from RAP to develop the following list of potential measures:

Efficiency Measures

- Weatherizing low-income residential buildings that use oil or propane for space heating
- Weatherizing non-low-income residential buildings that use oil or propane for space heating
- Doubling Vermont Gas's efficiency program efforts
- Weatherizing commercial buildings that use oil or propane for space heating

Electrification Measures

- Retrofitting cold climate heat pumps into oil and propane heated homes
- Retrofitting cold climate heat pumps into oil and propane heated commercial buildings
- Retrofitting heat pump water heaters into homes that heat water with oil or propane
- Extending utility power lines to maple sugar houses (eliminating diesel generator usage)
- Custom electrification measures for large commercial or industrial businesses

Biofuel Measures

- Developing wood-fueled district heating projects
- Developing combined heat and power (CHP) projects for waste water treatment plants (burning methane produced on-site)
- Retrofitting wood pellet or wood chip boilers for schools
- Retrofitting wood pellet evaporators for maple sugaring
- Retrofitting wood pellet boilers to displace oil or propane heat in homes
- Retrofitting liquid biofuel heating systems into homes currently using oil or propane

Renewable Electricity

- Installing photovoltaic panels on residential or business roofs

This list is consistent with the Vermont Climate Action Commission's recent recommendations to the Governor.[2] Note that the list is not intended to be exhaustive. It focuses primarily on measures that target the most likely opportunities for substantially reducing carbon emissions from Vermont buildings (e.g., weatherizing buildings, electrifying space heating, and and/or heating with biofuels). However, to give a flavor for the potentially wide range of options available, it also includes some more niche opportunities being targeted by some of Vermont's utilities as part of their plans to meet the state's

[2] Vermont Climate Action Commission, Executive Order No. 12-17 Report to the Governor, July 31, 2018 (https://anr.vermont.gov/sites/anr/files/Final%20VCAC%20Report.pdf).

Renewable Portfolio Standards Tier III requirements to help their customers reduce fossil fuel consumption. The list also addresses "measures" at a relatively high level, focusing on measure bundles whenever appropriate (e.g. characterizing an average home "weatherization package" rather than separately characterizing the many insulation, air sealing and other individual measures that might be part of such packages).

Selection of a Subset of Measures for Analysis

Because this project had a limited budget and timeline for completion, we needed to constrain analysis to a subset of the potential measures listed above. Several factors were considered when deciding which measures to pursue, including the magnitude of the potential CO_2 emissions reductions, the ability to access and use already well-vetted measure-characterization assumptions (costs, savings, useful life, etc.), and a desire for some balance among efficiency, electrification, and biofuel options.

In consultation with RAP, we selected for analysis the following five measures:

- Residential low-income weatherization of oil and propane heated homes
- Residential non-low-income weatherization of oil and propane heated homes
- Retrofitting of cold climate heat pumps into homes heated with oil or propane
- Retrofitting heat pump water heaters into homes whose water is heated with oil or propane
- Retrofitting schools with wood pellet boilers to displace oil heat.

Again, this is just a subset of an already non-exhaustive list of potential options, so these measures should be viewed solely as illustrative examples of the kinds of measures that can be pursued.

Measure Characterizations

EFG relied on the following sources for estimating the average costs, savings, and measure lives for each of the five measures we characterized:

- **Residential low-income weatherization**. The average cost per job and average fossil fuel savings per job were derived from the Vermont Weatherization Assistance Program's Report to the Vermont Legislature on its FY17 (July 2016 through June 2017) program year.[3] Note that we do not include the modest reductions in electricity consumption that should result from reductions in run times of furnace fans and hot water circulator pumps. This is a conservative bias against the measure. We assumed a 25-year life for the savings.

[3] Geoff Wilcox, Weatherization Program Administrator, Vermont Agency of Human Services, Department for Children and Families, "Performance Indicators for the Vermont Weatherization Assistance Program", January 31, 2018.

- **Residential non-low-income weatherization**. We estimated savings for non-low-income weatherization assuming an average annual baseline consumption of 82.8 MMBtu and 20% energy savings. The baseline consumption of 82.8 MMBtu is based on the assumed average Vermont home's fossil fuel consumption in the Vermont RPS Tier III planning tool.[4] The 20% energy savings factor is consistent with the average achieved in recent years by Efficiency Vermont's whole house retrofit program.[5] Again, we do not include the benefits associated with modest reductions in electricity consumption that should result from reductions in run times of furnace fans and hot water circulator pumps. The cost per unit of savings was assumed to be the same as for low income retrofits. Again, we assumed a 25-year life for the savings.
- **Cold climate heat pumps**. Costs, fossil fuel savings, corresponding increases in electricity consumption, and measure lives for cold climate heat pumps were derived from the Vermont RPS Tier III planning tool and *Efficiency Vermont*'s Technical Reference Manual. We assumed a 50/50 split between single-head and multi-head systems, as well as an even distribution of different capacities characterized within the Tier III tool. Note that the Tier III planning tool assumes electricity consumption will be added in the summer (as well as in winter) because heat pumps offer the ability to provide cooling (as well as heating). Based on other analyses we have performed,[6] it is far from clear that heat pump retrofits will appreciably increase cooling energy use relative to what customers would otherwise have installed. However, we have used the Tier III planning tool assumptions as is.
- **Heat Pump Water Heaters**. Costs, fossil fuel savings, corresponding increases in electricity consumption, and measure lives for heat pump water heaters were all derived from the Vermont RPS Tier III planning tool. Note that these assumptions adjust for impacts of heat pump water heaters on space heating (because they scavenge heat from conditioned spaces), but conservatively do not account for any cooling or dehumidification savings and their related economic benefits.
- **Wood pellet boilers for schools**. The average fossil fuel consumption for schools – and therefore the average fossil fuel reduction that could be achieved by retrofitting wood pellet boilers – was based on data from the 180 Vermont schools currently using oil for space heating, as documented in an extensive database maintained by the Vermont Department of Forest, Parks, and Recreation. The cost of retrofitting a pellet boiler was based on an estimated average

[4] The Tier III Planning Tool was developed by the Vermont Energy Investment Corporation, in conjunction with Vermont's electric utilities and the Vermont Department of Public Service.

[5] The program's average savings was 20% in 2016 (Keith Levenson and Jeanne Elias, "Annual Report of the Department of Public Service on Vermont's Progress Toward Building Energy Goals Pursuant to 10 V.S.A. § 581", December 21, 2017) and 17% in 2017 (Keith Levenson, "Annual Report of the Department of Public Service on Vermont's Progress Toward Building Energy Goals Pursuant to 10 V.S.A. § 581", December 28, 2018).

[6] For example, see Neme, Chris, *"Comparative Analysis of Fuel-Switching from Oil or Propane to Gas or Advanced Electric Heat Pumps in Vermont Homes"*, filed as part of testimony on behalf of the Vermont Public Interest Research Group (VPIRG) and Kristin Lyons in Docket 7970 before the Vermont Public Service Board, May 6, 2015.

cost $175,000 per MMBTUh of output capacity provided by Adam Sherman of the Biomass Energy Resource Center (a program of the Vermont Energy Investment Corporation).[7] We estimated that the average school has a 1.22 MMBTUh load by dividing the estimated average annual oil consumption by the default commercial building full load hour assumption (1417) in the Efficiency Vermont cost-effectiveness screening tool. We assumed such boilers have an average life of 30 years.

For the two weatherization measures and the cold climate heat pump measure we focused on the retrofitting of nearly 60% of Vermont homes that heat with either fuel oil propane. Based on U.S. Census data,[8] we assumed that 73% of such homes currently heat with oil and 27% with propane. For heat pump water heaters, we focused on nearly 50% of Vermont homes that currently have oil or propane water heaters. Based on data from a 2013 study on the relative use of those two fuels in Vermont for water heating,[9] we assumed 76% of such homes would displace oil and 24% would displace propane.

To estimate the lifetime reduction in CO_2 emissions from each measure we used the following U.S. Energy Information Administration emission factors for oil and propane:[10]

Fuel oil:	73.16 kg/MMBtu
Propane:	63.07 kg/MMBtu

Note that when estimating the effect on CO_2 emissions for the two electrification measures (cold climate heat pump and heat pump water heaters) we needed to subtract increased CO_2 emissions resulting from increased electricity consumption from the CO_2 emission savings associated with displacing oil or propane in order to estimate the *net* effect of electrification. To estimate CO_2 emissions from the Vermont electric grid we first multiplied the kWh consumption estimated for the electrification measures by the current national average emissions rate for gas-fired power plants (itself based on an average heat rate of 7812 Btu/kWh from the U.S. Energy Information Administration's December 2018 Monthly Energy Review, Table A6).[11] The resulting emissions rate – 914 lbs/MWh – is right in the middle of the New England Independent System Operator's estimates of its 2016 average (707 lbs/MWh) and

[7] 1/18/19 email
[8] https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_5YR_B25040&prodType=table
[9] NMR Group, "Vermont Single-Family Existing Homes Onsite Report", prepared for the Vermont Department of Public Service, 2/15/13 (https://publicservice.vermont.gov/sites/dps/files/documents/Energy_Efficiency/EVT_Performance_Eval/VT%20SF%20Existing%20Homes%20Onsite%20Report%20-%20final%20021513.pdf)
[10] https://www.eia.gov/environment/emissions/co2_vol_mass.php
[11] https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

marginal (1007 lbs/MWh) emissions rates.[12] Finally, using assumptions in the Vermont RPS Tier III planning tool, we adjusted that gas power plant emissions rate down by the percent of Vermont's electricity consumption that is forecast to come from renewable energy sources over the life of the measures.

The resulting measure characterizations for each measure analyzed are summarized in Table 1 below.

Table 1: Average Fossil Fuel Savings, Lives, CO_2 Reductions, and Capital Costs of Selected Measures

Measures	Per Unit Measure Assumptions			
	Fossil Fuel Savings (MMBtus)	Measure Life (Years)	Lifetime CO2 Reduced (Metric Tons)	Capital Cost
Efficiency				
Non-low income weatherization	17	25	29	$5,650
Low Income weatherization	26	25	45	$8,804
Electrification				
Cold Climate Heat Pumps	26	15	24	$4,288
Heat Pump Water Heaters	12	13	9	$1,660
Biofuels				
Wood Pellet boilers for schools	1723	30	3780	$212,742

Program Characterizations

To analyze the CO_2 emissions reduction potential of programs to promote the individual measures described above, we needed to develop several additional assumptions. They are:

- **Rebate levels**. This is the portion of the incremental capital costs of the measures that a program to promote them would cover, as a way of inducing customers to invest in the measures. For many measures, rebate levels have a substantial impact on program participation. We assumed that the level of ambition for the programs would be aggressive, but below the level of effort and financial support required to achieve maximum participation. For non-low-income weatherization, cold climate heat pump retrofits and heat pump water heater retrofits, we assumed rebates would cover half of the costs of the measures. For wood pellet boiler retrofits in schools, we assumed rebates would cover 75% of the cost, in recognition of the more significant barriers school districts often face when considering substantial capital investments. For low-income weatherization, we assumed that the program would cover 100% of the measure costs, just as the current state weatherization assistance program does.

[12] https://www.iso-ne.com/static-assets/documents/2018/01/2016_emissions_report.pdf

- **Non-rebate costs**. Programs to promote the five different measures described above would need to incur additional costs, beyond the cost of any measure rebates, to manage the programs, market the programs, provide technical assistance, conduct quality control inspections, evaluate the programs, etc. We have expressed those costs as a percentage of the measure costs. Programs promoting single products, like cold climate heat pumps and heat pump water heaters, have lower non-rebate costs (we assume such costs are equal to 20% of rebate costs). Programs that require more technical support, like weatherization programs wood pellet boiler retrofits in schools, have higher non-rebate costs (we assume equal to 30% of rebate costs). Note that the non-rebate cost for low income weatherization – equal to 11% of rebate costs[13] – is relatively low in part because the technical support costs are assumed to be part of the reported average job cost.
- **Multi-Year Program Participation**. For the purpose of this analysis, we focused on the number of customers we thought would participate in aggressive 10-year statewide programs targeting each of these measures. To develop those estimates we relied on the same sources used to estimate oil and propane use for the measure characterizations described above: U.S. Census data for weatherization programs and cold climate heat pumps; a Vermont baseline study for heat pump water heaters; and the Vermont Forest, Parks and Recreation database for oil heated schools. We then used our professional judgment, based on more than two decades worth experience working across the country on efficiency and electrification programs, to inform estimates of the portion of those markets that could be reached through aggressive programs over the next decade. For low income weatherization, we assume that the number of oil or propane homes treated would be approximately twice the number of total low income homes currently weatherized through the state's Home Weatherization Assistance Program.[14]

A summary of these assumptions for each of the five measures analyzed is presented in Table 2.

[13] According to Geoff Wilcox, the Vermont Weatherization Program Administrator, 10% of the grants to the state's community action agencies for delivering weatherization services are to cover administration costs (personal communication, January 2019). That is equal to 11% "adder" to the actual weatherization measure costs (0.1 / 0.9 = 0.11).

[14] Note that this will require more than doubling the total number of low-income weatherization jobs performed each year because not all homes weatherized by the program have oil or propane heat. We have assumed that an average of 1800 oil and propane heated low income homes would be weatherized each year over the next decade. Over the 2017 program year, the Vermont Weatherization Assistance Program weatherized 893 homes (Geoff Wilcox, "Performance Indicators for the Vermont Weatherization Assistance Program", Report to the Vermont Legislature, January 31, 2016). If two-thirds of those homes – or about 600 – were oil or propane heated, and the portion of oil or propane heated homes remained unchanged, the total number of homes served by the program would need to triple to reach our target for oil and propane weatherization jobs.

Table 2: Program Assumptions for Selected Measures

Measures		Program Assumptions			
		Rebate as % of Measure Capital Cost	non-rebate program cost (as % of rebate)	10 Year Eligible Market	10 Year Market Penetration
Efficiency					
	Non-low income weatherization	50%	30%	110,939	50,000
	Low Income weatherization	100%	11%	41,032	18,000
Electrification					
	Cold Climate Heat Pumps	50%	20%	151,971	75,000
	Heat Pump Water Heaters	50%	20%	126,682	35,000
Biofuels					
	Wood Pellet boilers for schools	75%	30%	180	90

Cost-Effectiveness Analysis

We assessed the cost-effectiveness of each of the five measures, at both the individual measure level and a program level, from two different perspectives:

- **A "total cost" perspective**: At the measure level, this compares the *total* cost of an average measure – both the portion of the measure cost covered by a program rebate and the remaining measure cost paid by the participating customer[15] – to the energy benefits (i.e. reduction in fuel costs) produced. For the program level analysis, the average measure cost and benefits are multiplied by the number of forecast participants; non-rebate program costs (for administration, marketing, quality control inspections, evaluation, etc.) are also added.
- **A "program cost" perspective**: At the measure level, this compares just the average program *rebate* cost to the energy benefits (i.e. reduction in fuel costs). At the program level, the average program rebate cost and energy benefits are multiplied by the number of forecast participants; non-rebate program costs are also added.

[15] Note that heat pump water heater retrofits displace existing functioning oil or propane water heaters that are assumed to be (on average) half way through their useful lives. Thus, among other impacts, such retrofits have the effect of pushing the date on which a new water heater would otherwise have had to be purchased further into the future (on average, by the useful life of water heaters divided by two). Under the total cost perspective, this is treated as a cost savings, partially offsetting the initial up-front cost of the retrofit. Though such cost "credit" could theoretically also be associated with wood pellet boiler retrofits in schools, we have conservatively not included it for that measure because of uncertainty over how long schools would endeavor keep even older existing boilers operational (often past their theoretical useful lives), as well as the potential need to retain such boilers for back up. These cost "credits" are realized solely by the program participants, so they are not part of the program cost perspective.

For simplicity only, we assume the same number of measures are installed in each of the next ten years.

All measure and program cost-effectiveness calculations are performed and presented below in net present value (NPV) terms. The NPV calculations were performed using the Efficiency Vermont cost-effectiveness screening tool. The tool includes detailed electricity, fuel oil, propane, and wood pellet cost projections for the next fifty years. It should be noted that these are forecasts of avoidable future marginal wholesale costs, which tend to be lower – at least for regulated electric and gas utilities – than the retail energy prices customers pay because retail energy prices include some costs that cannot be avoided (e.g., payment for past electric distribution system investments that need to be recovered). The tool also includes load shapes for different electricity end uses, so that the energy (differentiated by season and time of day), peak capacity, and transmission and transmission and distribution (T&D) system impacts[16] of increasing electricity consumption associated with cold climate heat pumps and heat pumps water heaters are fully captured. We also used the tool's default 3% real discount rate.

Note that the result of this approach is that the cost-effectiveness analysis under both perspectives is conservative because it excludes a number of additional benefits associated with the various measures we analyzed. Among these are:

- the value of avoided environmental externalities (not just from reductions in carbon emissions, but from reductions of nitrous oxide emissions, particulate emissions and a variety of other pollutants);
- the value of increased flexibility to the grid associated, for example, with the ability to used electric water heaters as storage to enable balancing of the system as it relies increasingly on non-dispatchable renewables;
- the value of other non-energy benefits to consumers (e.g. improved comfort, improved health and safety and improved building durability that weatherization programs often provide); and
- the risk-mitigating value of efficiency measures (e.g. reducing exposure to future fuel price volatility).

Had we monetized these benefits, the cost-effectiveness of the measures and programs would be greater than we present in the Results section below. Put another way, our analysis conservatively understates the true societal benefits and net benefits of the measures and programs analyzed.

[16] The Efficiency Vermont cost-effectiveness screening tool implicitly assumes that there are substantial T&D costs associated with electrification measures. There has been significant debate in recent years regarding the extent to which there would be T&D costs associated with electrification, particularly if heat pumps and heat pump water heaters are controlled (for example, see Chapter 6 of Green Mountain Power's 2018 Integrated Resource Plan at https://greenmountainpower.com/regulatory/2018-integrated-resource-plan/). However, we have used the Efficiency Vermont screening tool T&D cost assumptions as is.

Results

Measure Cost-Effectiveness

Table 3 below presents the average per-unit cost-effectiveness of each measure under each of the two perspectives analyzed. The NPV values shown are for discounting costs and benefits back to 2018. They represent the average 2018 NPVs of the same number of participants in each year from 2019 through 2028.[17] As the table shows, all of the measures are cost-effective under both the "program perspective" and the "total cost perspective".

Table 3: Measure-Level Cost-Effectiveness[18]

	Total Cost Perspective				Program Cost Perspective			
Measures	NPV Costs	NPV Benefits	NPV Net Benefits	BCR	NPV Costs	NPV Benefits	NPV Net Benefits	BCR
Efficiency								
Non-low income weatherization	$4,891	$6,958	$2,066	1.42	$2,446	$6,958	$4,512	2.84
Low Income weatherization	$7,622	$10,814	$3,192	1.42	$7,622	$10,814	$3,192	1.42
Electrification								
Cold Climate Heat Pumps	$3,712	$4,219	$506	1.14	$1,856	$4,219	$2,362	2.27
Heat Pump Water Heaters	$627	$1,397	$770	2.23	$719	$1,397	$679	1.94
Biofuels								
Wood Pellet boilers for schools	$184,175	$509,368	$325,193	2.77	$138,131	$509,368	$371,236	3.69

Program Cost-Effectiveness

Table 4 below presents cost-effectiveness results for the 10-year programs we envisioned for promoting each of the measures in Table 3. They are the average costs and benefits per measure in Table 3 multiplied by the number of forecast program participants shown in the last column of Table 2, with estimated non-rebate program costs added (which is why the benefit-cost ratios are a little lower than the measure-level results presented in Table 3. The results are presented in millions of dollars.

[17] In other words, they are the average 2018 NPV of 10% of customers installing the measure in 2019, 10% installing it in 2020, 10% installing it in 2021 and so on (out to 10% in 2028). For costs, this means that the average is something akin to the 2018 NPV of a 2023 or 2024 installation, which would be less than the equipment cost because of five or six years of discounting, before adding non-rebate program costs. The same would be true of benefits, except that benefits do not stay constant in real dollars over time like costs are assumed to do, because fuel prices are not forecast to increase exactly at the rate of inflation.

[18] Note that though we label these results as cost-effectiveness of "measures" – because we present

Table 4: Program-Level Cost-Effectiveness (millions of 2018$)

	Total Cost Perspective				Program Cost Perspective			
Measures	NPV Costs	NPV Benefits	NPV Net Benefits	BCR	NPV Costs	NPV Benefits	NPV Net Benefits	BCR
Efficiency								
Non-low income weatherization	$281	$348	$67	1.24	$159	$348	$189	2.19
Low Income weatherization	$152	$195	$42	1.28	$152	$195	$42	1.28
Electrification								
Cold Climate Heat Pumps	$306	$316	$10	1.03	$167	$316	$149	1.89
Heat Pump Water Heaters	$27	$49	$22	1.81	$30	$49	$19	1.62
Biofuels								
Wood Pellet boilers for schools	$20	$46	$26	2.26	$16	$46	$30	2.84

As the table shows, all of the programs we analyzed are cost-effective. In fact, all would provide at least $10 million in net benefits under the total cost perspective and at least $19 million in net benefits under the program cost perspective. Again, neither of these perspectives account for CO_2 emission reduction benefits, let alone other environmental benefits, the potential value of increased flexibility on the electric grid, other participant benefits like improved comfort, or the risk-mitigating value of efficiency.

CO_2 Emission Reduction Potential and Costs of Reductions

Table 5 below presents the total amount of lifetime CO_2 emissions reduction that each 10-year program is estimated to be able to provide, along with the average annual program cost/budget and the levelized costs per metric ton of CO_2 emissions reduction. As the table shows, two of the programs analyzed – weatherizing non-low-income homes and retrofitting cold climate heat pumps into oil and propane heated homes – have larger CO_2 emissions reduction potential than the others. Note the results for each program are not entirely additive, as there would be some modest interactive effects between weatherizing homes and retrofitting them with heat pumps that we have not accounted for in the CO_2 emissions reduction estimates.

Table 5: CO_2 Emission Reduction Potential and Its Net Cost

Measures	Lifetime CO2 Reduced from Measures Installed over 10 Prog Yrs (Metric Tons)	Average Annual Program Budget (millions of 2018 $)	Levelized $/Ton of Lifetime CO2 Reduced (Total Cost Perspective)	Levelized $/Ton of Lifetime CO2 Reduced (Program Perspective)
Efficiency				
Non-low income weatherization	1,458,078	$18	($75)	($212)
Low Income weatherization	817,850	$18	($84)	($84)
Electrification				
Cold Climate Heat Pumps	1,795,531	$19	($8)	($119)
Heat Pump Water Heaters	314,094	$3	($97)	($83)
Biofuels				
Wood Pellet boilers for schools	340,222	$2	($131)	($152)

It should also be noted that for most of the programs we analyzed the estimated CO_2 emissions reductions and economic impacts presented are the total impacts that could be achieved through aggressive, 10-year, statewide initiatives. Our estimates of CO_2 emission reductions and the program costs of achieving them are not adjusted for the portion of customers who may make such investments on their own, absent the programs envisioned for this analysis (or "free riders" in energy efficiency program parlance). Nor are those impacts – or the program budgets presented – adjusted to account for the impacts of programs currently being implemented in the state by various parties. However, based on our understanding of the current market and programs in the state, the combination of free riders and non-free rider participants in existing state programs will not amount to anything close to the levels of participation we have forecast and therefore nowhere close the levels of CO_2 emissions reduction, economic impacts or program budgets we have estimated.[19] Nor would accounting for such impacts have a material impact on our conclusions regarding program cost-effectiveness. Moreover, it is likely that the kind of programs that our analysis envisions would lower the current costs of some of the measures over time due to increased market familiarity and economies of scale. We have not accounted for any such potential market transformation benefits in our analysis.

[19] For example, our analysis forecasts about 5000 non-low income home oil or propane heat weatherization jobs per year. In contrast, Efficiency Vermont completed just 653 comprehensive thermal retrofits completed by in 2017 (Keith Levenson, "Annual Report of the Department of Public Service on Vermont's Progress Toward Building Energy Goals Pursuant to 10 V.S.A. § 581", December 28, 2018).