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ADDRESSING PARTICULATE MATTER AIR POLLUTION FROM VIRGINIA'S TRANSPORTATION SECTOR

Prepared for Virginia Clean Cities
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Acknowledgements & Disclaimer

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Disclaimer

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Honor Pledge

On my honor as a student, I have neither given nor received aid on this assignment.

Executive Summary

Residents of Virginia's metropolitan areas are exposed to dangerously high levels of particulate matter air pollution from cars, trucks, and buses. Particulate matter (PM2.5) emissions are associated with respiratory, cardiovascular, neurologic diseases, and death (Virginia Clinicians for Climate Action, 2019). Motor vehicles, which are the leading source of PM2.5 emissions in Virginia, emit both particulate matter directly and PM2.5 precursor gasses. The effects of PM2.5 emissions from on-road vehicles are disproportionately borne by low-income communities and communities of color, who are more likely to live near major roads where concentrations of air pollutants can be about 3 times higher than average. These disadvantaged communities see higher rates of asthma and other respiratory diseases - including higher COVID-19 death rates - and higher rates of PM2.5 exposure-related mortality.

High emissions from Virginia's transportation sector are the result of too many conventional fuel vehicles and too little electric vehicle uptake. There is clear evidence that electric vehicles have the capacity to reduce PM2.5 emissions, and they are becoming increasingly feasible and affordable as technology continues to advance. Battery electric vehicles have no tailpipe emissions, and the emissions produced by electricity generation are lower than those produced by the average gasoline car and decreasing. Driving range, lack of charging infrastructure, and high up-front costs have been the biggest barriers to EV uptake in Virginia thus far. Virginia needs to increase uptake of electric vehicles, especially among its lower income residents, in order to tackle its transportation emissions problem.

To address the problem of transportation emissions in Virginia, I consider the following policy alternatives:

1. Fund the Electric Vehicle Rebate Program
2. Establish an Electric Vehicle Tax Credit
3. Set Electric Vehicle Supply Equipment (EVSE) requirements at Multi-Unit Dwellings (MUDs)
4. Authorize Virginia's participation in the Transportation and Climate Initiative Program (TCI-P)

After evaluating each alternative on the criteria of cost effectiveness, equity, political feasibility, and administrative feasibility, I recommend that the General Assembly **fund the Electric Vehicle Rebate Program.** The program, which was established during the 2021 Special Session after passing on party lines, makes electric vehicle purchasers eligible for a rebate of $2,500, with qualified purchasers whose annual household income is less than 300 percent of the current poverty guidelines eligible for an additional $2,000 enhanced rebate. Passing a budget amendment to allocate funding to the program would allow it to become operational in the next fiscal year. Across the United States, rebates have proven to be effective at increasing EV uptake. The program incorporates an equity metric into its design, and it is highly administratively feasible and easy to implement.

Introduction

Problem Statement

Residents of Virginia's metropolitan areas are exposed to dangerously high levels of particulate matter air pollution from cars, trucks, and buses. The transportation sector is Virginia's largest emitter of particulate matter, accounting for nearly half of the state's particulate matter (PM2.5) emissions. PM2.5 particles are particularly dangerous for human health because they are easily inhaled and have been consistently linked to significant long-term health impacts and increases in mortality, even at levels below National Ambient Air Quality Standards.

Client Overview

My client is Virginia Clean Cities (VCC), a non-profit that works with vehicle fleets, fuel providers, community leaders, and other stakeholders to save energy and promote the use of domestic fuels and advanced vehicle technologies in transportation. The organization's primary interest is in promoting policies that increase electric vehicle (EV) use, decrease barriers to EV adoption, and reduce dependence on petroleum-based fuels. As Virginia's environmental justice initiatives are just now getting off the ground, VCC is interested in sharing information with state policymakers for a comprehensive policy addressing clean transportation issues, particularly for historically disadvantaged communities.

Background

Transportation emissions generate substantial external costs

Extensive evidence has linked road transport with a number of negative externalities, including environmental impacts from CO2 emissions, health impacts from particulate matter air pollution, deaths and injuries from accidents, and lost productivity due to congestion and noise (Bjertn, 2019). Emissions from the transportation sector impose particularly high external costs. Internal emissions cost an average of 0.085 cents per vehicle-kilometer traveled (VKT), while external emissions cost 1.92 cents/VKT, meaning drivers bear just 4% of the total emissions costs of their road transport (Cui and Levinson, 2020). Globally, transport is responsible for about a third of CO2 emissions, and three quarters of those emissions come from road travel (Ritchie, 2020). These trends hold when narrowed to the national level. Transportation accounted for 29% of total US greenhouse gas emissions in 2019, making it the nation's largest emissions source, with on-road vehicles accounting for 75% of those emissions (EPA, 2021). From 1990 to 2019, emissions from on-road vehicles increased 28.9%. Bus emissions, which saw a 162% increase over that period, were the primary driver of this change (EPA, 2021). Narrowing to the state level, transportation is also Virginia's largest source of air pollution, currently accounting for 45% of the Commonwealth's carbon dioxide emissions (Lewis, n.d.). While Virginia's total carbon emissions are improving, having decreased by 20 percent from 2005 to 2015, limited progress has been made towards reducing emissions from the transportation sector in particular (Constible, 2018).

Air pollution from the transportation sector generates not only environmental costs, but substantial health costs. While CO2 emissions have important consequences, particulate matter (PM) particles are a much more harmful pollutant for human health. PM2.5 particles, which have a diameter of less than 2.5 microns, are particularly dangerous because they are easily inhaled and can cause stroke, heart disease, respiratory disease, and death ("Transit Solutions for the Air Quality Crisis," 2020). Considerable research links PM exposure to significant long-term health impacts and increases in mortality (Di et al., 2017; Goodkind et al., 2019; Lin et al., 2002; De Moura & Reichmuth, 2019). Even at levels below National Ambient Air Quality Standards, increases in PM2.5 exposure are associated with increases in the risk of death (Di et al., 2017). In fact, the World Health Organization estimates that particulate matter exposure causes 4.2 million deaths per year ("Transit Solutions for the Air Quality Crisis," 2020). Motor vehicles emit both particulate matter directly and PM2.5 precursor gasses. As a result, hot spots with substantially elevated PM2.5 levels tend to emerge near major roadways (Mukherjee et al., 2020). Data from New York revealed that children living within 200 meters of high-traffic volume roads were significantly more likely to be hospitalized for asthma (Lin et al., 2002). In 2011, over 100,000 premature deaths were linked to PM2.5 exposure, and 28% of those deaths were attributable to transportation pollution (Goodkind et al., 2019).

Costs of transportation emissions are disproportionately borne by disadvantaged communities

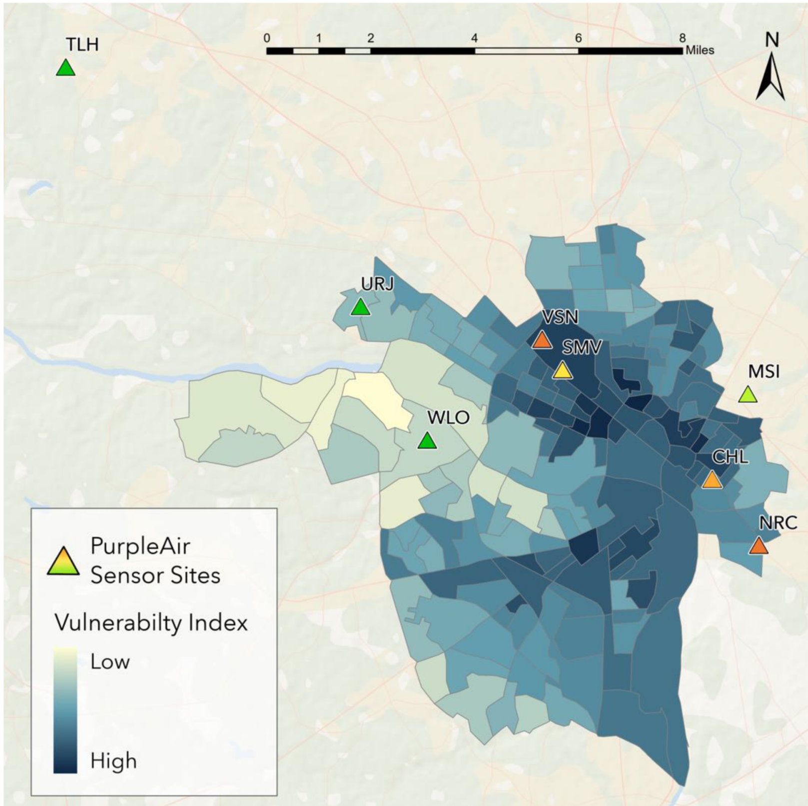
Across the United States, people of color and low income people consistently face disproportionately high levels of exposure to PM2.5 emissions (EPA, 2019; Mikati et al., 2018;

Miranda et al., 2011). While disadvantaged communities are exposed to higher levels of pollution, they tend to contribute to those pollution levels the least, making these disparities even more inequitable (Sider et al., 2015). Air pollution is highest in highly segregated metropolitan areas, and disparities between racial groups are wider in these areas too (Morello-Frosch and Jesdale, 2006); Yu and Stuart, 2017). When broken down by components, disparities in PM2.5 exposure are even larger. Hispanics and non-Hispanic Blacks have higher exposure than non-Hispanic whites for 12 out of the 14 PM2.5 components, and people below the poverty threshold have higher exposure than those above the threshold for 11 of those components (Bell and Ebisu, 2012).

Focusing particularly on air pollution from vehicles and the transportation sector, evidence also reveals that communities of color and low-income communities face disproportionate levels of exposure (Clark et al., 2017; Demetillo et al., 2021; Gunier and Hertz, 2003; De Moura and Reichmuth, 2019; Rowangould, 2013). In California, the lowest-income households live where particulate matter pollution from transportation is 10% higher than the state average, while particulate matter pollution is 13% below the state average for the highest-income households (Reichmuth, 2019). Children of color and low-income children in the state are more likely to live in high-traffic areas with higher potential exposure to vehicle emissions (Gunier and Hertz, 2003). These trends are consistent with national census and traffic data, which show that racial minorities are disproportionately likely to live near major roads, where concentrations of air pollutants are about 3 times higher than average (Rowangould, 2013; Karner et al., 2010). In 2010, non-whites were 2.5 times as likely as whites to live in areas with transportation pollution levels above WHO guidelines, and they were exposed to 37% more NO2 than whites (Clark et al., 2017). Emissions from diesel trucks and commuter traffic are primarily responsible for these disparities in NO2 pollution (Demetillo et al., 2021).

These disparities in exposure to transportation emissions have substantial implications for health outcomes in disadvantaged communities. Nationally, the effect of PM2.5 exposure on mortality is highest for racial minorities and low-income people, with larger disparities in cities with bigger populations (Di et al., 2017; Demetillo et al., 2017). These disadvantaged communities see higher rates of asthma and other respiratory diseases, including higher COVID-19 death rates (Goetz et al., 2021). In Virginia specifically, the most socially vulnerable communities bear a disproportionate share of the state's air pollution-related health costs (Industrial Economics, Inc., 2020). PM2.5-attributable mortality rates are 61% higher in Virginia's most vulnerable Census tracts than in its least vulnerable Census tracts (Industrial Economics, Inc., 2020). Richmond is among the localities with the highest overall pollutant levels and share of pollution from transportation. Richmond's 3-year average annual mean PM2.5 concentration from 2018-2020 was 7.8 $\mu g/m^3$, 16.4% higher than the state average concentration (Virginia DEQ, 2020). Within Richmond, the most socially vulnerable and low-income communities experience significantly higher concentrations of PM2.5 air pollution (Eanes et al., 2020). This trend is consistent with evidence from across the state and country on the disparate impacts of PM2.5 emissions on disadvantaged communities.

Figure 1: Variance in Hourly Average PM2.5 Concentrations in Richmond, 2019



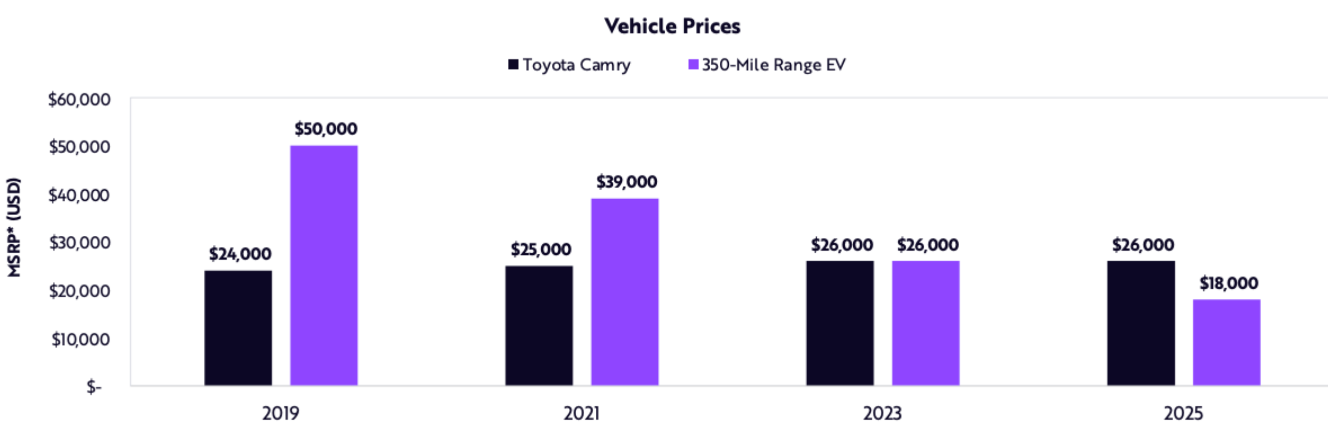
Eanes et al., 2020

Strategies for reducing transportation emissions

As evidence on the profound environmental and health impacts of transportation across the United States has accumulated, several states have begun to implement policies aiming to reduce transportation emissions. Many of these policies which focus on reducing overall emissions, however, disproportionately benefit higher-income, white communities which bear the smallest share of the costs of transportation emissions. Low carbon fuel standards have been a popular policy response across the country. Although switching from gasoline to biofuels such as ethanol has the potential to reduce GHG emissions from transportation, there is evidence that biofuels and biofuel refineries could contribute to at least as much outdoor air pollution as gasoline (Shonkoff et al., 2011). Fuel switching could disproportionately burden low-income communities and communities of color, who are most likely to live near both highways and refineries. Low emissions zones, which either charge or prevent high polluting vehicles from entering certain areas, and congestion charging, which imposes a fee on all cars entering a high-traffic zone, also aim to reduce emissions from the transportation sector. While there is evidence that each of these policies reduce PM2.5 levels, they may also have regressive effects upon low-income individuals who may not be able to afford low-emissions vehicles and may have less job flexibility allowing them to avoid congestion zones (Transit Solutions for the Air Quality Crisis, 2020).

Across the United States and worldwide, there is consistent evidence that vehicle electrification has tremendous potential to reduce emissions from the transportation sector (Becker, 2009; Choma et al., 2020; Horton et al., 2021; Nichols et al., 2015). While the magnitude of emissions reductions depends on how electricity is generated, vehicle electrification reduces emissions, PM2.5-attributable mortality, and health costs even when EVs are powered by fossil fuel plants (Choma et al., 2020; Becker, 2009; Horton et al., 2021). Urban areas experience the largest benefits from vehicle electrification (Choma et al., 2020; Nichols et al., 2015). Technological advances are currently contributing to rapid increases in EV driving range and decreases in production costs, making vehicle electrification one of the most feasible policies for reducing transportation emissions. As soon as 2023, the cost of a standard electric vehicle is expected to be comparable to that of a conventional fuel vehicle (Bhutata, 2021). As electricity generation technology continues to advance, EVs are expected to provide even greater impacts on air pollution over the next several decades (Holland et al., 2020).

Figure 2: Forecasted Prices of Electric Vehicles and Conventional Fuel Vehicles, 2019-2025



ARK Investment Management LLC, 2020

Electric vehicles have the greatest potential benefits for non-White households, low-income households, and households in neighborhoods with high levels of pollution (Bauer, 2021; Ju et al., 2020). However, EV access is disproportionately low for these communities. Rates of EV adoption are substantially higher in high-income neighborhoods, and Black and Latino car buyers make up only 12% of EV buyers but 41% of conventional fuel vehicle buyers (Bauer, 2021). This trend is largely due to the fact that the burden of vehicle ownership is much higher for low-income households, and EVs have prohibitively high up-front costs (Bauer, 2021). The most popular EV incentive policies, such as rebates and tax credits, can contribute to disproportionate access for low-income households if they do not include targeted equity metrics. Across the United States, clean energy rebates and tax credits have disproportionately been issued to high-income, white households (Ju et al., 2020; Borenstein and Davis, 2016). In part because of the inequitable distribution of these EV incentive policies, the benefits of reduced air pollution from electric vehicle adoption primarily accrue to high income households (Holland et al., 2019).

In March 2021, Virginia joined 12 other states and Washington D.C. in adopting a zero-emissions vehicle (ZEV) program with the goal of increasing electric vehicle manufacturing and sales in the state (Boehmer, 2021). Benefits from the ZEV program are estimated to reach about $102 million in 2035 from reductions in PM2.5-related mortality and morbidity, with the greatest benefits accruing to more densely populated urban areas (Industrial Economics, Inc., 2020). The widespread evidence on the potential benefits of vehicle electrification for low-income communities and communities of color in particular suggest that policymakers aiming to reduce transportation emissions exposure for these communities should focus their efforts around expanding equitable access to electric transportation.

Criteria

I consider the following criteria when evaluating potential policy alternatives for reducing Virginia's transportation emissions. For each criterion, I rank each alternative as **low (1)**, **moderate (2)**, or **high (3)**. I then weight each criterion based on its importance to the alternative's overall success at addressing the problem.[1]

Cost Effectiveness

The policy should achieve the maximum amount of PM2.5 emissions reduction per dollar spent.

To calculate the cost of each alternative, I take into account all direct costs including program funding, implementation and ongoing administration, any materials or equipment needed, and any financial incentives involved in the alternative. I use the Department of Planning and Budget's Fiscal Impact Statements as a guide for determining the costs of bills that have already been introduced. For alternatives that have not been introduced in Virginia's legislature, I predict the costs based on similar policies that have been implemented in other states. I use a discount rate of 3%, adjusted for 2% annual inflation.

I measure the effectiveness of each alternative by calculating the expected annual reduction in PM2.5 emissions from implementing the policy. For those alternatives aimed at increasing Virginia's concentration of electric vehicles, I use the expected increase in the number of electric vehicles sold from each alternative to estimate its expected impact on PM2.5 emissions. Since electric vehicles reduce mobile PM2.5 emissions by 81% compared to conventional fuel vehicles, and mobile emissions account for 11% of total PM2.5 emissions, each EV is expected to reduce PM2.5 emissions by 0.0891% (The Potential for Electric Vehicles to Reduce Vehicle Emissions and Provide Economic Benefits in the Wasatch Front, 2017). The expected increase in electric vehicle concentration is based on policies that have been implemented in other states whenever possible.

Low = Over $2 billion per percent PM2.5 reduction
Moderate = $1-2 billion per percent PM2.5 reduction
High = Less than $1 billion per percent PM2.5 reduction

Equity

The policy should target reductions in PM2.5 emissions exposure towards Virginia's most socially vulnerable communities.

[1] I assign the highest weight (35%) to equity because the problem's costs are disproportionately borne by disadvantaged communities. I assign 30% weight to administrative feasibility because the urgency of the problem makes the ability to take immediate action especially important. I assign 20% weight to political feasibility because while any policy will need to receive political support in order to be implemented, political constraints are malleable and likely to change over time. Finally, I assign cost effectiveness the lowest weight (15%) because this problem imposes enormous costs on the Commonwealth, so policy change is necessary even if it is very costly.

This criterion rates each alternative on the extent to which it "promotes program access to communities and populations that face disproportionately high and adverse health, environmental, social, and economic burdens, including minority populations and low-income populations," which was a criterion established in Virginia's 2020 Electric Vehicle Incentive Working Group Feasibility Report. Equity is made up of a series of three indicators for targeting, differential effects, and universality. The maximum equity score is 3, and the minimum equity score is -1.

1. **Targeting:**
   - 1 point if the policy explicitly targets benefits towards low-income communities or communities of color
   - 0 points if the policy does not explicitly target benefits towards low-income communities or communities of color
2. **Differential effects:**
   - 1 point if the policy is expected to result in greater benefits for low-income communities or communities of color
   - 0 points if the policy is not expected to have differential effects
   - -1 point if the policy is expected to result in greater costs for low-income communities or communities of color
3. **Universality:**
   - 1 point if the benefits of the policy are not conditional on purchasing an Electric Vehicle
   - 0 points if the benefits of the policy are conditional on purchasing an Electric Vehicle.

Low = equity score of -1 to 0
Moderate = equity score of 1
High = equity score of 2 to 3

Political Feasibility

The policy should be acceptable to relevant legislators with decision-making power.

I assign each alternative a political feasibility score based on the number of legislators expected to support the policy. In the Virginia General Assembly, there are 40 Senators and 100 Delegates. Currently, there are 21 Democrats and 19 Republicans in the Senate and 48 Democrats and 52 Republicans in the House of Delegates. Senators serve 4-year terms, while Delegates serve only 2-year terms. To predict support, I will examine legislators' past voting records, political affiliations, committee assignments, and any statements they may have made in support of or against the policy or similar proposals.

Low = Not expected to receive the support of a majority of members from either house of the General Assembly
Moderate = Expected to receive the support of a majority of either Delegates or Senators (one house)
High = Expected to receive the support of a majority of both Delegates and Senators

Administrative Feasibility

The policy should be simple and easy to implement.

Each alternative will be scored based on the number of steps it requires to reach the implementation stage of the policy process.

Low = more than 12 steps
Moderate = between 7 and 12 steps
High = 6 or fewer steps

Alternatives

Alternative 1: The General Assembly should approve a budget amendment to provide funding for the Electric Vehicle Rebate Program.

In the 2021 special session, the General Assembly established an Electric Vehicle Rebate Program which makes electric vehicle purchasers eligible for a rebate of $2,500, with qualified purchasers eligible for an additional $2,000 enhanced rebate (Electric Vehicle Rebate Program, 2021).[2] The final budget, however, included no funding for the program. Republicans had unanimously voted against the bill, and lawmakers cited the need to further refine program design and fine-tune details of the rebate before allocating funding (Vogelsong, 2021). However, the Electric Vehicle Incentive Working Group's Feasibility Report contains detailed recommendations for the implementation of an EV rebate program in Virginia (Electric Vehicle Incentive Working Group Feasibility Report, 2020). This alternative proposes that the General Assembly include funding for the rebate program in the budget for fiscal years 2023 and 2024. During the 2022 regular session, Delegate Reid introduced Item 121 #1h, which would allocate $40 million per year for fiscal years 2023 and 2024 from the general fund to the Electric Vehicle Rebate Program Fund (121#1h, 2022). Based on the Department of Taxation's predicted demand for the rebates, I recommend that the General Assembly allocate $30 million per year for fiscal years 2023 and 2024 (HB 1979 Fiscal Impact Statement, 2022).

The purpose of the rebate is to incentivize electric vehicle uptake in Virginia, particularly among low- and moderate-income purchasers. An analysis of electric vehicle incentives across the US found that every $1000 offered as a rebate or tax credit increases EV sales by an average of 2.6% (Jenn et al., 2020). Incorporating equity metrics, such as an income cap or higher vouchers for lower income consumers, to target these vouchers to low-income households increases their equity and cost effectiveness and maximizes EV sales (DeShazo et al., 2017). Allocating $30 million to the Electric Vehicle Rebate Program would allow for the subsidization of about 7,000 to 10,000 electric vehicle purchases annually.[3]

Cost Effectiveness

During the 2021 Special Session, the Department of Planning and Budget published a Fiscal Impact Statement for HB 1979, which created the Electric Vehicle Rebate Program. In it, the Department of Taxation (TAX) provides estimates of demand for the rebates in the first five years of the program. TAX projects that annual demand will start at just under over $26 million and will increase over the first five years of the program. The Fiscal Impact Statement also projects that the cost of funding the Electric Vehicle Rebate Program may include additional staff or the cost of a contractor for the Department of Mines, Minerals, and Energy (DMME). The average salary of a DMME employee was $70,125 in 2020 (*Department of Mines, Minerals and Energy Salaries*, 2021). Because

[2] "Qualified purchasers" are defined by Va. Stat. § 45.2-1726 as those whose annual household income is less than 300 percent of the current poverty guidelines.
[3] $30,000,000 / $2,500 per non-qualified purchaser = 12,000 vehicles. $30,000,000 / $4,500 per qualified purchaser = 6,666 vehicles. Assuming a mix of qualified and non-qualified purchasers, the rebate program is expected to subsidize between 7 and 10 thousand EV purchases annually.

DMME anticipates that "indeterminate" additional resources would be required to support the development and implementation of the Electric Vehicle Rebate Program, I assume administrative costs of $70,125 for one additional staff member or contractor, with a 2% annual raise. To calculate the total cost of this alternative, I add that administrative cost to the TAX demand projections for the first five years of the program, discounting future costs at a rate of 3%, for a total cost of $217,032,790.38.

According to a 2014 analysis of the effect of various financial incentives on Electric Vehicle sales, each $1,000 increase in financial incentives is expected to cause a country's EV market share to increase by 0.06% (Sierzchula et al., 2014). Since TAX projects that 25% of rebates from the program will be to individuals who qualify for the enhanced $4,500 rebate, while the remaining 75% of rebates granted will be $2,500, this alternative is expected to increase EV sales by 0.18%. Since electric vehicles reduce mobile PM2.5 emissions by 81% compared to conventional fuel vehicles, and mobile emissions account for 11% of total PM2.5 emissions, each EV is expected to reduce PM2.5 emissions by 0.0891% (The Potential for Electric Vehicles to Reduce Vehicle Emissions and Provide Economic Benefits in the Wasatch Front, 2017). Using those numbers, this alternative is expected to reduce PM2.5 emissions by about 5.13% in the first 5 years of the program.

Dividing total costs by emissions reduction, this alternative is expected to cost $4,230,205,760.11 per percent PM2.5 emissions reduction in the first five years of the program. Since its cost is greater than $2 billion per percent PM2.5 emissions reduction, this alternative scores **low** on cost effectiveness.

Equity

Virginia's Electric Vehicle Rebate Program explicitly targets benefits towards low-income communities by offering a $2,000 enhanced rebate to low-income purchasers. Therefore, it receives 1 point for targeting. It also receives 1 point for differential effects. An analysis comparing different designs for Electric Vehicle rebate programs projected that a policy offering EV purchasers a uniform $2,500 rebate with a vehicle price cap of $60,000 would result in 45% of rebate dollars being allocated to households with incomes under $75,000 (DeShazo et al., 2017). Since Virginia's program would offer an additional $2,000 rebate to purchasers with household income below 300% of poverty guidelines, qualified purchasers would receive 80% more dollars per rebate granted than non-qualified purchasers. Therefore, we would expect that about 81% (1.80*0.45) of rebate dollars would be allocated to households with below-median income, resulting in greater benefits for low-income communities. Because the benefits of the rebate are conditional on purchasing an electric vehicle, this alternative receives 0 points for universality. In total, this alternative receives 2 equity points, which is a **high** equity score.

Administrative Feasibility

Virginia's Electric Vehicle Rebate Program is fully formulated and ready for implementation, but the final budget from the 2021 session did not provide funding for the rebate (Vogelsong, 2021). For the rebate to become functional the following steps would be needed:

1. Budget amendment with funding for the rebate passes House
2. Budget amendment passes Senate

3. Governor approves the budget
4. DMME develops process for verifying eligible purchasers and sets up website for program administration
5. Stakeholders lobby officials who hold appointment authority to make appointments to the Electric Vehicle Rebate Program Advisory Council
6. Legislative and executive officials make appointments to the Advisory Council

In total, 6 steps are expected to be necessary for the policy to reach implementation, giving it a **high** administrative feasibility score.

Political Feasibility

While Delegate David Reid and Senator Jennifer McClellan put forward budget amendments requesting that funding for the Electric Vehicle Rebate Program be included in the budget for the next two fiscal years, neither the budget proposed by the House nor the Senate include any funding for the EV rebate program (Vogelsong, 2022). In addition, Governor Youngkin has signaled that he is not interested in pursuing the policy (Reid, 2022). Despite support from auto dealers and electric vehicle manufacturers, this alternative is not expected to receive support from a majority of Senators nor Delegates without additional lobbying efforts, so it receives a **low** political feasibility score.

Alternative 2: The General Assembly should establish an electric vehicle tax credit.

Purchasers of qualifying new electric vehicles are currently eligible for a federal income tax credit of up to $7,500, and four states (Colorado, Kansas, Louisiana, and Oklahoma) currently offer state income tax credits for alternative fuel vehicle (AHV) purchasers (Alternative Fuels Data Center: Federal and State Laws and Incentives, n.d.). Tax credits are the most popular incentive to increase EV adoption. In 2019, Colorado extended its AHV tax credit for the purchase and lease of electric vehicles in particular (Ruedebusch, 2019). This alternative proposes that Virginia's General Assembly pass legislation establishing a refundable state income tax credit for the purchase or lease of a new electric vehicle, using Colorado's electric vehicle tax credit as a model. In Colorado, more than 12,000 households received a state tax credit to purchase a plug-in electric vehicle from 2017 to 2020 (Brasch, 2020). More than 80 percent of those households reported an annual income of more than $100,000 a year. Unlike other state incentives, the Colorado rebate does not exclude high-income households or luxury car models, but the legislature has separate efforts to expand electric car access.

This tax credit would be intended to reduce the cost of alternative fuel vehicles and incentivize their purchase for all purchasers. While Virginia's law allows for both refundable and non-refundable income tax credits, a refundable tax credit would better serve Virginia's taxpayers by allowing filers to receive a refund check if the amount of the credit exceeds their tax liability (Electric Vehicle Incentive Working Group Feasibility Report, 2020). The amount of the tax credit would vary based on gross vehicle weight rating (GVWR),[4] with passenger electric vehicles eligible for up to $2,500 for purchase or $1,500 for lease, light-duty electric trucks eligible for up to $3,500 for purchase or $1,750 for lease,

[4] Light duty electric trucks have a gross vehicle weight rating (GVWR) of less than 10,000 pounds, medium duty electric trucks have a GVWR of 10,000 pounds to 26,000 pounds, and heavy duty electric trucks have a GVWR of 26,000 pounds or more (Colorado General Assembly, n.d.).

medium-duty electric trucks eligible for up to $5,000 for purchase or $2,500 for lease, and heavy-duty electric trucks eligible for up to $10,000 or $5,000 for lease. The tax credit would begin in tax year 2023 and expire in tax year 2028.

Cost Effectiveness

To calculate the expected cost of establishing an Electric Vehicle Tax Credit in Virginia, I use data on the number of credits claimed and cost of Colorado's Electric Vehicle Tax Credit in the first 5 years of its program (Colorado Department of Revenue Annual Report, 2021). Because Virginia's current EV market share is about double Colorado's 2014 EV market share (the year before their tax credit was established), I assume that demand for EV tax credits in Virginia today will be about double the demand for credits in Colorado during the first 5 years of its program. For that reason, I convert Colorado's cost estimates from 2014 to 2020 dollars, and I multiply the cost by two to estimate the cost of administering a similar program in Virginia. Using that method, the expected cost of this alternative over the first 5 years of the program is $184,583,776.15.

Because the tax credits offered by this program would vary based on vehicles' gross vehicle weight rating and based on purchase or lease, I assume that the average tax credit will be $3,500. Based on this assumption, and the assumption that each $1,000 increase in financial incentives will increase EV market share by 0.06%, I project that this alternative will increase EV sales by 0.21% (Sierzchula et al., 2014). Assuming 0.0891% PM2.5 emissions reduction per EV, this alternative is expected to reduce PM2.5 emissions by about 5.99% in the first 5 years of the program.

Dividing total costs by emissions reduction, this alternative is expected to cost $3,081,926,652.93 per percent PM2.5 emissions reduction in the first five years of the program. Since its cost is greater than $2 billion per percent PM2.5 emissions reduction, this alternative scores **low** on cost effectiveness.

Equity

The amount of the EV tax credit does not vary by income and there is no income cap. Because it does not explicitly target benefits towards low-income communities or communities of color, it receives 0 points for targeting. This policy is also not expected to result in greater benefits for high-income households than for low-income households. In Colorado, 80% of electric vehicle credits from 2017-2020 were redeemed by households earning more than the state's median income (Brasch, 2021). Similarly, Federal EV tax credits are disproportionately claimed by higher-income households, with 78% of tax credits being claimed by households with income of $100,000 or more (Congressional Research Service, 2019). While it would not grant greater benefits to communities of color or low income communities, it would not impose disproportionate costs on those communities either. For that reason, this alternative receives 0 points for differential effects. Finally, since eligibility for the tax credit is conditional upon purchasing an electric vehicle, this alternative receives 0 points for universality, giving it a **low** total equity score.

Administrative Feasibility

While Virginia legislators were largely supportive of the Federal EV tax credit, legislators at the state level have not moved to establish a state tax credit, as some other states have done. Rather, the General Assembly focused its EV incentive efforts on establishing the Electric Vehicle Rebate Program in 2021, so an electric vehicle tax credit is not currently on Virginia's policy agenda. I anticipate that the following steps would be necessary for the implementation of an EV tax credit:

1. General Assembly convenes a working group to study the feasibility of an EV tax credit
2. Working group meets for one year, studying tax credit design
3. Working group publishes a report with recommended EV tax credit design
4. Legislation establishing the EV tax credit is introduced
5. Stakeholders lobby the General Assembly to support the policy
6. Legislation passes House
7. Legislation passes Senate
8. Governor approves legislation
9. Funding for the tax credit is included in the budget
10. Budget with funding for tax credit passes House
11. Budget with funding for tax credit passes Senate
12. Governor approves the budget
13. Department of Taxation sets up a process and website for administration of the tax credit

In total, I anticipate that 13 steps will be needed for the policy to reach implementation, giving this alternative a **low** administrative feasibility score.

Political Feasibility

In 2020, the General Assembly tasked the Department of Mines, Minerals and Energy with convening a working group to determine the feasibility of an electric vehicle rebate program for Virginia. In their feasibility report, the Electric Vehicle Incentive Working Group considered the potential for a refundable EV tax credit and determined that it "would not be universally applicable and may limit accessibility to the desired equity populations" (Electric Vehicle Incentive Working Group Feasibility Report, 2020). For that reason, an electric vehicle tax credit has become politically unpopular among Virginia legislators. Since we would not expect a majority of legislators in either house of Virginia's legislature to support this alternative without a major change in the political landscape, it scores **low** on political feasibility.

Alternative 3: The General Assembly should establish Electric Vehicle Supply Equipment (EVSE) requirements for multi-unit dwellings (MUDs).

This alternative proposes that the General Assembly require new MUD developments with 5 or more units to install Electric Vehicle Supply Equipment (EVSE) at least 10 percent of off-street parking spaces. Similar requirements exist in California and New Jersey (CALGreen, 2019; Multi-Unit Dwelling EV Charging Incentive Program, 2022). This requirement would apply to all new construction of MUD developments beginning in FY 2023. It would require developments to have installed EV-Ready EVSE in 10 percent of parking spaces prior to occupancy.

Studies indicate that 85% of EV charging occurs at home, and access to home charging is one of the biggest barriers to EV uptake. Less than half of drivers living in apartments have access to home charging compared to over 80% of those in detached houses (Nicholas et al., 2019). MUDs are disproportionately inhabited by low-income residents, with almost half of these households making an income of less than $35,000, so this disparity has substantial equity implications (Huether, 2021). The lack of charging in multi-unit dwellings presents a chicken-and-egg problem; private companies are not incentivized to build public charging infrastructure in low-income communities because of low EV adoption, but the lack of charging infrastructure in these communities is a barrier to EV uptake. Currently, under the Virginia Right to Charge law, associations such as HOAs or condo boards can't prohibit unit owners or lessees from installing an electric vehicle charging station, but the unit owner must pay the full cost of installation (Lanny, 2020). Requiring developers to install EVSE at all new MUD developments would increase construction costs, but would also draw demand by making it cheaper for tenants to charge in the long run. Additionally, including EV-Ready infrastructure during the initial construction of a parking lot allows developers to avoid 75% of the retrofit cost (Salcido et al., 2021).

Cost Effectiveness

According to several estimates, installation of EV-Ready Electric Vehicle Siting Equipment (EVSE) at new construction costs about $900 per parking space (Salcido et al., 2021; Nicholas, 2019). In 2021 there were 14,400 new multi-unit residential building permits in Virginia, and each MUD building has, on average, 150 parking spaces (Virginia Realtors, n.d.; Right Size Parking, n.d.). Since this alternative would require developers to install EV-Ready EVSE infrastructure in 10% of parking spaces at all new MUD construction, the expected cost of installation is $32,400,000 per year. Over the first five years after policy implementation, the expected cost of this alternative is $157,342,190.58.

In a model of the effects of various strategies for increasing EV adoption, researchers found that each additional charging station per 100,000 residents that a country added would increase its EV market share by 0.12% (Sierzchula et al., 2014). I calculate the projected increase in EV sales from this alternative by multiplying the number of new charging stations per 100,000 residents by 0.12%. This results in a projection that this alternative will increase EV market share by 0.30% annually. Assuming 0.0891% PM2.5 emissions reduction per EV, this alternative is expected to reduce PM2.5 emissions by about 8.68% in the first 5 years of the program.

Dividing total costs by emissions reduction, this alternative is expected to cost $1,813,423,307.53 per percent PM2.5 emissions reduction in the first five years of the program. Since its cost is between $1-2 billion per percent PM2.5 emissions reduction, this alternative scores **moderate** on cost effectiveness.

Equity

This policy does not explicitly target benefits toward low-income communities or communities of color, so it receives 0 points for targeting. Instead, it institutes a universal requirement for all multi-unit dwellings in Virginia. However, MUD residents are disproportionately low-income. In fact, almost half of households living in MUDs make less than $35,000 (Huether, 2021). Just 25% of apartment-dwellers make $75,000 or more (National Multifamily Housing Council, 2019). Therefore, the benefits of this policy are expected to be greater for low-income communities and communities of color, so this alternative receives 1 point for differential effects. The benefits of this policy will accrue only to electric vehicle purchasers/owners, so it receives 0 points for universality. This results in a **moderate** total equity score.

Administrative Feasibility

Strategies for expanding EVSE access, particularly with a focus on equity, are being discussed by Virginia lawmakers and some legislation has already been enacted to increase charging accessibility. For instance, the General Assembly passed a "right to charge" law in 2020, which requires homeowner and condominium associations to allow residents to install charging infrastructure in their designated parking space (McGowan, 2021). However, details of a policy requiring developers to install charging infrastructure at new MUD development construction would need to be more fully formulated before implementation. For that reason, I anticipate that the following steps would be required for the implementation of this policy:

1. Stakeholders convene to determine the specific details of EVSE requirements for MUDs
2. Legislation establishing EVSE requirements for MUDs is introduced
3. Legislation passes House
4. Legislation passes Senate
5. Governor approves legislation
6. Funding for administrative cost is included in the budget
7. Budget with funding for EVSE passes House
8. Budget with funding for EVSE passes Senate
9. Governor approves the budget
10. MUD developers are notified of the policy change
11. A system for oversight and enforcement is established

There are a total of 11 steps necessary for the policy to reach implementation, giving this alternative a **moderate** administrative feasibility score.

Political Feasibility

Both Republican and Democratic lawmakers have recognized the need for EVSE expansion in Virginia. In 2020, the "right to charge" law unanimously passed the House of Delegates, and it passed the Senate with only one "No" vote (SB 630, 2020). Since this alternative builds upon the intentions of the right to charge law, it is feasible to expect that a majority of both House and Senate members would support it, so it scores **high** on political feasibility.

Alternative 4: The General Assembly should approve legislation to authorize Virginia's participation in the Transportation and Climate Initiative Program ("TCI-P").

TCI-P is a cap-and-trade program that requires suppliers of transportation fuel to purchase allowances for the amount of carbon their product emits above a certain amount (Virginia Should Join

The Transportation and Climate Initiative Program, 2021). TCI-P regulates three categories of parties: position holders (owners of transportation fuel at large bulk terminals), distributors (companies that deliver fuel to filling stations), and terminal operators of large bulk fuel facilities (Transportation and Climate Initiative Program Model Rule Summary, 2021). Massachusetts, Connecticut, Rhode Island, and the District of Columbia launched the program in 2020 (Transportation and Climate Initiative, 2020). TCI-P functions much like the Regional Greenhouse Gas Initiative (RGGI), which Virginia has participated in since 2020. Just as a portion of RGGI revenue is allocated towards mitigating the effects of climate change, TCI-P would generate revenue for Virginia and require that at least 35 percent of those funds be invested to improve transportation programs in marginalized communities. Each state develops an implementation plan outlining how it will invest its proceeds. The General Assembly would need to pass authorizing legislation in order for Virginia to participate in TCI-P.

Cost Effectiveness

Virginia's TCI-P carbon market proceeds are expected to accrue to over $1 billion in its first five years of participation (TCI Carbon Market Proceeds Estimator). While the costs of TCI-P include establishing an Administrative Organization to provide administrative support and technical assistance and engaging in program monitoring and review, TCI-P is expected to be mostly self-funding (TCI-P Elements of Program Design, 2020). I estimate the administrative costs of TCI-P based on the current administrative costs of Virginia's participation in RGGI, which TCI-P is modeled after. According to a Department of Planning and Budget Fiscal Impact Statement, RGGI costs the state $185,600,000 per year for staff and administration. By subtracting Virginia's anticipated costs from revenue over the first five years of participation, at a discount rate of 3%, this alternative is expected to generate $335,727,343,465.40 in net revenue.

The TCI Carbon Market Proceeds Estimation Tool also includes estimates of state emissions reduction from participation. Based on these projections, PM2.5 emissions in Virginia are expected to decrease by about 0.13% in the first 5 years of participation in the market. Since this alternative will be generating net revenue while reducing emissions, it receives a **high** cost effectiveness score.

Equity

This alternative receives 1 point for targeting because the TCI-P model rule explicitly states that 35% of the revenue generated from the cap-and-trade market must be invested in marginalized communities. However, it receives -1 point for differential effects. Because TCI-P will substantially raise costs for fuel suppliers, gasoline and diesel prices are expected to increase between 5 and 17 cents per gallon if suppliers pass along those costs to consumers (McGowan, 2021). Gas taxes are regressive, meaning the effects of this price increase will disproportionately harm low-income Virginians. This is especially true given that Virginia has not yet implemented a policy such as a rebate reducing the up-front cost of EVs, so low-income purchasers are less able to afford low-emissions and zero-emissions vehicles. Joining TCI-P receives 1 point for universality, since its benefits are not conditional on purchasing an electric vehicle. This results in a **moderate** overall equity score.

Administrative Feasibility

Stakeholders have been urging Virginia lawmakers to join TCI-P since it was established in 2020. In fact, over 100 businesses and institutions joined together in 2020 to urge governors in the region, including Virginia, to join TCI-P (Booth-Tobin, 2020). Former Governor Northam was influential in shaping the program, and it is currently being discussed by relevant stakeholders (Savage, 2021). While TCI-P is on the policy agenda, the General Assembly would need to take several steps before fully implementing the program:

1. Agencies responsible for implementation develop a plan outlining how TCI-P proceeds will be invested
2. Legislation to authorize Virginia to join TCI-P is introduced
3. Legislation passes House
4. Legislation passes Senate
5. Governor approves legislation
6. Funding for TCI-P is included in the budget
7. Budget with funding for TCI-P passes House
8. Budget with funding for TCI-P passes Senate
9. Governor approves budget
10. Agencies responsible for implementation establish carbon markets and processes for administration
11. Suppliers of transportation fuel are notified of new regulation

The total number of steps necessary is 11, giving this alternative a **moderate** administrative feasibility score.

Political Feasibility

TCI-P is modeled after the Regional Greenhouse Gas Initiative (RGGI), which Virginia joined in 2020. During the 2022 General Assembly session, a bill to withdraw Virginia from RGGI passed the House of Delegates but was struck down in the Senate (HB 1301, 2022). Support of RGGI likely closely predicts support of TCI-P, so this alternative would likely receive support from a majority of Senators, but would not receive support from a majority of Delegates. This results in a **moderate** political feasibility score.

Outcomes Matrix

	Rebate	Tax Credit	EVSE Requirement	TCI-P
Cost Effectiveness (x 0.15)	1	1	2	3
Equity (x 0.35)	3	1	2	2
Political Feasibility (x 0.20)	1	1	3	2
Administrative Feasibility (x 0.30)	3	1	2	2
Total	2.30	1.00	2.20	2.15

Recommendation & Implementation

Based on analysis of each alternative's cost effectiveness, equity, political and administrative feasibility, I recommend Alternative 1, that the General Assembly **allocate funding for the Electric Vehicle Rebate Program**. While the cost of this alternative will be substantial, it is by far the most administratively feasible policy, meaning the benefits of implementation will begin to accrue more quickly than any other option. It is also the most equitable policy, which is critically important since communities of color and low income communities are disproportionately burdened by PM2.5 emissions in Virginia.

Implementation Overview

Virginia legislators and stakeholders have already spent several years studying the feasibility of an Electric Vehicle Rebate Program and developing a plan for its implementation. In 2018, the Virginia Energy Plan listed EV adoption as a major goal for the Commonwealth over the next several years (Virginia Energy Plan, 2018). In 2020, Governor Northam tasked the Departments of Mines, Minerals and Energy (DMME), Environmental Quality (DEQ), Motor Vehicles (DMV), and Taxation (TAX), with convening a working group to study the feasibility of an EV rebate program. After convening with a variety of stakeholder groups, the working group determined that there was "universal interest in incentives to support the adoption of electric vehicle technology in Virginia (Electric Vehicle Incentive Working Group Feasibility Report, 2020)." Their published report concluded that an EV rebate program would provide substantial economic and environmental benefits to Virginia. It proposed a program design and laid out a plan for program administration, implementation, and performance review, making the implementation of this policy simple and straightforward.

Under the rebate program, any Virginia resident who purchases a new or used electric vehicle from a participating dealer will be eligible for a rebate of $2,500, plus an additional $2,000 if they are a qualified purchaser. The rebate will be applied at point-of-sale, and the dealer will be reimbursed by DMME for each rebate.

Stakeholders Involved

The Department of Mines, Minerals, and Energy will be responsible for administration of the Electric Vehicle Rebate Program. Virginia Code § 45.2-1726 instructs the Department to develop and implement a process for verifying eligible purchasers, to establish a website for administration of the program and update it weekly about available funds, and to assess and report annually on the program's effectiveness. The DMV may also be involved with the implementation of the program, since the commissioner is responsible for verifying eligibility for the rebate.

Additionally, the program calls for the establishment of an Electric Vehicle Rebate Program Advisory Council for monitoring and evaluation of the program. The Advisory Council will consist of three legislative members and 13 non-legislative members, appointed by various state government officials. While the Council has existed in name since the rebate program was established in 2021, those citizen members have not yet been appointed (Interim Studies & Commission Listings, 2022).

Motor vehicle dealers will also be heavily involved in the administration of the rebate program. For that reason, the DMME is required to include instructions on the EV rebate program website for how dealers should process a reimbursement for a rebate. Dealers will also have representation on the Advisory council. Two members of the council will be motor vehicle dealers, one will represent a new vehicle dealer association to which a majority of new motor vehicle dealers in Virginia belong, and the Executive Director of the Motor Vehicle Dealer Board will serve ex officio with voting privileges (Va. Code § 45.2-17, 2021).

Program Evaluation

The Code section establishing the Electric Vehicle Rebate Program also lays out requirements for program monitoring and evaluation. The purpose of the Advisory Council is to monitor the implementation and operation of the program, regularly assess the effect of the rebate on increasing electric vehicle sales, and recommend to DMME whether any adjustments or changes should be made. It is required to report annually on the relative price of electric motor vehicles compared with the price of traditional motor vehicles, and whether the amount of the rebate should be adjusted to reflect the rate of inflation (Interim Studies & Commission Listings, 2022). Additionally, the Director of DMME is required to submit an annual report on the administration and implementation of the program, along with any recommended changes, to the Governor and the General Assembly. Specifically, the Department must report on whether the allocation of Rebate Program funds should be adjusted and whether it should be amended to include an income cap. These implementation processes will help the General Assembly to determine whether the program is meeting its goals of increasing electric vehicle uptake and doing so in an equitable way. In fact, the Advisory Council is specifically instructed to "consider the goal of increasing electric vehicle awareness and adoption in developing and making its recommendations (Interim Studies & Commission Listings, 2022)."

Challenges to Implementation

The success of the Electric Vehicle Rebate Program's implementation depends upon the cooperation of those responsible for administering the program. Throughout the legislative process, the rebate program has received pushback from Republicans and some Democrats. Governor Youngkin has expressed that the program is not among his administration's priorities, which presents an obstacle to implementation even if funding for the program is included in the budget. Members of Youngkin's administration, who will be responsible for making appointments to the Advisory Council, may attempt to inhibit the implementation of the program by stalling those appointments. However, the General Assembly is currently struggling to come to an agreement on the budget for the next two fiscal years, which presents a unique opportunity to overcome these political hurdles.

Delegate Reid, who has been a key advocate for the rebates, should use the current stalemate as an opportunity to bargain with relevant decision makers and convey the urgency and importance of the rebate program's implementation. My client, Virginia Clean Cities, has strong relationships with lawmakers, transportation industry members, and other stakeholders. They should mobilize this coalition to market the rebate program to both Republicans and Democrats. Framing the rebate program as an economic tool to attract large battery and electric vehicle manufacturers to Virginia would appeal to Republican lawmakers. Framing it as an equity initiative that would make EVs more accessible for low-income households, who are disproportionately impacted by rising gas prices, would appeal to Democrats (Reid, 2022).

Conclusion

Emissions from on-road vehicles cost Virginia billions each year, contributing to premature deaths, hospitalizations, and thousands of lost work hours. Those mortality and morbidity effects are disproportionately borne by members of low-income communities and communities of color. Virginia must take action to address its transportation emissions problem. The most immediate, concrete way the General Assembly can do so is by funding the Electric Vehicle Rebate Program.

Of course, a rebate program alone will not go far enough to reduce transportation emissions in Virginia. In order for the state to transition to a zero-emissions transportation sector, this policy will need to be combined with investments in charging infrastructure, public transit and fleet electrification, and supply-side strategies. Virginia is already taking steps towards some of those goals. The state currently offers transit emissions reductions grants, alternative fuel school bus and infrastructure loans, and alternative fuel vehicle incentives to localities ("Laws and Incentives VA," n.d.). However, Virginia is not doing enough to incentivize and make electric vehicle uptake more accessible for individuals, particularly those from low-income communities and communities of color. There is no question that electric vehicles provide widespread public health and economic benefits. By funding the Electric Vehicle Rebate Program, the General Assembly will facilitate a more equitable transition to zero-emissions transportation in Virginia.

Appendix

In calculating the cost effectiveness of each alternative, I made several assumptions. This appendix outlines those assumptions and the sensitivity of this analysis to each of them.

Alternative 1: Fund the Electric Vehicle Rebate Program

According to my initial analysis, funding the Electric Vehicle Rebate Program is expected to cost $4.23 billion per percent PM2.5 reduction, giving it a **low** cost effectiveness score. This estimate is not highly sensitive to the predicted administrative cost of the program, and it is somewhat sensitive to the predicted demand for the rebates.

Initial cost assumptions:

Cost	Y1	Y2	Y3	Y4	Y5
Rebates	26,600,000.00	29,400,000.00	41,600,000.00	57,000,000.00	69,600,000.00
Staff	70,125.00	71,527.50	72,958.05	74,417.21	75,905.56
Total	26,670,125.00	29,471,527.50	41,672,958.05	57,074,417.21	69,675,905.56

Initial model: Low cost effectiveness

Year	1	2	3	4	5	NPV
Costs	$ 26,411,191.75	$ 28,902,042.80	$ 40,470,928.66	$ 54,890,005.44	$ 66,358,621.72	$ 217,032,790.38
Emissions Reduction	1.022%	1.024%	1.026%	1.028%	1.030%	5.13%
Cost per % PM2.5 reduction	$ 2,583,197,430.37	$ 2,821,740,777.57	$ 3,944,125,423.33	$ 5,339,736,095.27	$ 6,443,811,824.33	**$ 4,230,205,760.11**

Major Assumptions

1. Administrative cost

In my initial analysis, I assume that DMME will need to hire one additional staff or contractor for the administration of the Electric Vehicle Rebate Program. I assume that each staff member will cost $70,125, which was the average salary of a DMME employee in 2020, and I assume a 2% raise each year (*Department of Mines, Minerals and Energy Salaries*, 2021). If I instead assume that DMME would need no additional staff to administer the program, it would still cost over $4 billion per percent PM2.5 reduction, meaning it would still score low on cost effectiveness.

Sensitivity 1: No administrative cost, low cost effectiveness

Year	1	2	3	4	5	NPV
Costs	$ 26,341,747.57	$ 28,831,897.45	$ 40,400,075.04	$ 54,818,436.40	$ 66,286,330.05	$ 216,678,486.51
Emissions Reduction	1.022%	1.024%	1.026%	1.028%	1.030%	5.13%
Cost per % PM2.5 reduction	$ 2,576,405,309.24	$ 2,814,892,402.86	$ 3,937,220,329.16	$ 5,332,773,811.87	$ 6,436,791,878.05	**$ 4,223,299,991.31**

2. Demand for rebates

In my initial analysis, I use the Department of Taxation's estimates of demand for the rebates, which are included in the Department of Planning and Budget's Fiscal Impact Statement for HB 1979. In order for the cost to fall below $2 billion per percent PM2.5 reduction, giving this alternative a moderate cost effectiveness score, I would need to assume that demand for the rebates will be 2.25x lower than the TAX estimates. In order for this alternative to score high on cost effectiveness, I would have to divide those estimates by 4.5.

Sensitivity 2: Demand/2.25, moderate cost effectiveness

		Year	1	2	3	4	5	NPV
Costs			$ 11,776,887.54	$ 12,884,322.00	$ 18,026,442.53	$ 24,435,318.55	$ 29,532,882.81	$ 96,655,853.43
Emissions Reduction			1.022%	1.024%	1.026%	1.028%	1.030%	5.13%
Cost per % PM2.5 reduction			$ 1,151,861,147.47	$ 1,257,911,664.87	$ 1,756,780,796.02	$ 2,377,083,977.57	$ 2,867,816,336.53	**$ 1,883,927,987.16**

Sensitivity 3: Demand/4.5, high cost effectiveness

		Year	1	2	3	4	5	NPV
Costs			$ 5,923,165.86	$ 6,477,233.68	$ 9,048,648.08	$ 12,253,443.79	$ 14,802,587.24	$ 48,505,078.65
Emissions Reduction			1.022%	1.024%	1.026%	1.028%	1.030%	5.13%
Cost per % PM2.5 reduction			$ 579,326,634.30	$ 632,380,019.79	$ 881,842,945.10	$ 1,192,023,130.49	$ 1,437,418,141.41	**$ 945,416,877.98**

Alternative 2: Establish an Electric Vehicle Tax Credit

According to my initial analysis, an electric vehicle tax credit is expected to cost just over $3 billion per percent PM2.5 reduction, giving it a **low** cost effectiveness score. This estimate is highly sensitive to assumptions about the cost of the program, and somewhat sensitive to assumptions about the average dollar amount of the tax credits granted.

Initial cost assumptions:

Cost	Y1	Y2	Y3	Y4	Y5
Colorado cost, in 2014 dollars	7,657,905.00	12,303,079.00	10,810,577.00	27,719,166.00	24,870,000.00
Colorado cost, in 2020 dollars	8,780,546.76	14,106,698.95	12,395,397.54	31,782,769.97	28,515,918.88
Virginia projected cost	17,561,093.51	28,213,397.89	24,790,795.08	63,565,539.94	57,031,837.77

Initial model: Low cost effectiveness

Costs	$ 17,390,597.46	$ 27,668,224.31	$ 24,075,720.71	$ 61,132,693.14	$ 54,316,540.54	$ 184,583,776.15
Emissions Reduction	1.193%	1.195%	1.198%	1.200%	1.203%	5.99%
Cost per % PM2.5 Reduction	$ 1,457,932,155.44	$ 2,314,691,079.05	$ 2,009,925,612.96	$ 5,092,876,611.03	$ 4,515,550,100.79	**$ 3,081,926,652.93**

<u>Major Assumptions</u>

1. Cost of tax credit in Virginia

Because Colorado's EV market share before the first year of their electric vehicle tax credit was about 1/2 of Virginia's current EV market share, I assume in my initial analysis that the cost of implementing an electric vehicle tax credit in Virginia would be 2x the cost of Colorado's program. In order for this alternative to reach a moderate cost effectiveness score, I would need to assume that the cost in Virginia would be only 1.25x that of Colorado. For this alternative to score high on cost effectiveness, I would need to assume that the cost of implementing an EV tax credit in Virginia would be just 0.6x Colorado's cost.

Sensitivity 1: 1.25x Colorado cost, moderate cost effectiveness

			1	2	3	4	5	NPV
Costs			$ 10,869,123.41	$ 17,292,640.19	$ 15,047,325.44	$ 38,207,933.21	$ 33,947,837.84	$ 115,364,860.09
Emissions Reduction			1.193%	1.195%	1.198%	1.200%	1.203%	5.99%
Cost per % PM2.5 Reduction			$ 911,207,597.15	$ 1,446,681,924.41	$ 1,256,203,508.10	$ 3,183,047,881.89	$ 2,822,218,812.99	**$ 1,926,204,158.08**

Sensitivity 2: 0.6x Colorado cost, high cost effectiveness

			1	2	3	4	5	NPV
Costs			$ 5,217,179.24	$ 8,300,467.29	$ 7,222,716.21	$ 18,339,807.94	$ 16,294,962.16	$ 55,375,132.85
Emissions Reduction			1.193%	1.195%	1.198%	1.200%	1.203%	5.99%
Cost per % PM2.5 Reduction			$ 437,379,646.63	$ 694,407,323.72	$ 602,977,683.89	$ 1,527,862,983.31	$ 1,354,665,030.24	**$ 924,577,995.88**

2. Average amount of tax credit

Because the amount of tax credit an individual can receive varies from $1,500 up to $10,000 based on the type of vehicle and whether it is purchased or leased, I assume in my initial analysis that the average dollar amount of EV tax credits granted would be $3,500. This alternative becomes moderately cost effective if I instead assume that the average amount of the tax credit will be $5,500. However, it does not become highly cost effective even if I assume that the average tax credit will be $10,000, which is the maximum credit possible and only applies towards the purchase of heavy-duty electric trucks.

Sensitivity 3: $5,500 average tax credit, moderate cost effectiveness

	1	2	3	4	5	NPV
Costs	$ 17,390,597.46	$ 27,668,224.31	$ 24,075,720.71	$ 61,132,693.14	$ 54,316,540.54	$ 184,583,776.15
Emissions Reduction	1.874%	1.881%	1.887%	1.893%	1.899%	9.43%
Cost per % PM2.5 Reductio	$ 927,775,008.01	$ 1,471,223,463.68	$ 1,275,985,793.74	$ 3,229,306,441.21	$ 2,859,808,940.92	**$ 1,956,524,770.52**

Sensitivity 4: $10,000 average tax credit, moderate cost effectiveness

	1	2	3	4	5	NPV
Costs	$ 17,390,597.46	$ 27,668,224.31	$ 24,075,720.71	$ 61,132,693.14	$ 54,316,540.54	$ 184,583,776.15
Emissions Reduction	3.408%	3.429%	3.449%	3.470%	3.491%	17.25%
Cost per % PM2.5 Reductio	$ 510,276,254.40	$ 807,001,168.60	$ 698,030,166.42	$ 1,761,856,134.42	$ 1,556,076,826.75	**$ 1,070,293,470.37**

Alternative 3: EVSE Requirements at MUDs

According to my initial analysis, requiring EVSE at all new multi-unit dwellings is expected to cost $1.8 billion per percent PM2.5 reduction. This results in a **moderate** cost effectiveness score. This estimate is highly sensitive to assumptions about the number of parking spaces at each new multi-unit dwelling, which determines how many new charging stations would need to be built. It is also highly sensitive to estimates of how much EVSE increases EV demand.

Initial assumptions:

Cost	
Cost per parking space	900
Number of new sites	14400
Number of parking spaces per site	150
Number of chargers needed per site	15
Total cost	32400000

Effectiveness	
Increase in EV market share per 100,000 residents	0.0000012
Virginia population 8.536 million	8536000
Number of new stations per 100,000 residents	2530.45923

Initial model: Moderate cost effectiveness

	1	2	3	4	5	NPV
Costs	$ 32,085,436.89	$ 31,773,927.80	$ 31,465,443.06	$ 31,159,953.32	$ 30,857,429.50	$ 157,342,190.58
Emissions Reduction	1.725%	1.730%	1.735%	1.741%	1.746%	8.68%
Cost per % PM2.5 reduction	$ 1,860,242,119.14	$ 1,836,604,572.45	$ 1,813,267,381.08	$ 1,790,226,728.49	$ 1,767,478,846.67	**$ 1,813,423,307.53**

Major Assumptions

1. Number of new chargers required

In my initial analysis, I assume that there will be an average of 150 parking spaces at each new multi-unit dwelling, meaning that each new MUD would be required to install EVSE in 15 parking spaces. If I increase that assumption to 170 parking spaces per site, the cost effectiveness of this alternative becomes low. If I decrease that assumption to 80 parking spaces per site, the cost effectiveness becomes high.

Sensitivity 2: 170 parking spaces per site, low cost effectiveness

	1	2	3	4	5	NPV
Costs	$ 41,211,961.17	$ 40,811,845.04	$ 40,415,613.53	$ 40,023,228.93	$ 39,634,653.90	$ 202,097,302.57
Emissions Reduction	1.955%	1.961%	1.968%	1.975%	1.982%	9.84%
Cost per % PM2.5 reduction	$ 2,108,274,401.69	$ 2,080,645,334.24	$ 2,053,378,347.44	$ 2,026,468,696.19	$ 1,999,911,697.61	**$ 2,053,549,561.65**

Sensitivity 3: 80 parking spaces per site, high cost effectiveness

	1	2	3	4	5	NPV
Costs	$ 9,126,524.27	$ 9,037,917.24	$ 8,950,170.47	$ 8,863,275.61	$ 8,777,224.39	$ 44,755,111.99
Emissions Reduction	0.920%	0.921%	0.923%	0.924%	0.926%	4.61%
Cost per % PM2.5 reduction	$ 992,129,130.21	$ 980,908,233.65	$ 969,814,244.48	$ 958,845,727.39	$ 948,001,263.30	**$ 969,904,017.03**

2. Increase in EV demand from EVSE

In my initial analysis, I assume that each additional charging station per 100,000 residents would increase Virginia's EV market share by 0.12% (Sierzchula et al., 2014). In order for the cost effectiveness of this alternative to become low, I only need to decrease that assumption by 0.02 percentage points, to a 0.10% increase in EV market share per additional charging station. If I increase that assumption to 0.22% per charging station, the cost effectiveness of this alternative becomes high.

Sensitivity 4: 0.10% increase in EV market share per charger, low cost effectiveness

	1	2	3	4	5	NPV
Costs	$ 32,085,436.89	$ 31,773,927.80	$ 31,465,443.06	$ 31,159,953.32	$ 30,857,429.50	$ 157,342,190.58
Emissions Reduction	1.437%	1.441%	1.445%	1.448%	1.452%	7.22%
Cost per % PM2.5 reduction	$ 2,232,290,542.97	$ 2,205,038,060.34	$ 2,178,118,284.31	$ 2,151,527,153.10	$ 2,125,260,654.52	**$ 2,178,311,696.59**

Sensitivity 5: 0.22% increase in EV market share per charger, high cost effectiveness

	1	2	3	4	5	NPV
Costs	$ 32,085,436.89	$ 31,773,927.80	$ 31,465,443.06	$ 31,159,953.32	$ 30,857,429.50	$ 157,342,190.58
Emissions Reduction	3.162%	3.180%	3.197%	3.215%	3.233%	15.99%
Cost per % PM2.5 reduction	$ 1,014,677,519.53	$ 999,263,371.98	$ 984,083,383.51	$ 969,133,996.95	$ 954,411,709.19	**$ 984,146,722.38**

Alternative 4: Authorize Virginia to join TCI-P

According to my initial analysis, TCI-P will result in net proceeds of over $300 billion per percent PM2.5 reduction, meaning it scores **high** on cost effectiveness. However, this estimate is highly sensitive to estimates of both projected proceeds and administrative cost.

Initial assumptions:

	1	2	3	4	5
Cost					
Projected Proceeds	$ (251,305,654.00)	$ (264,337,911.00)	$ (277,109,568.00)	$ (289,810,551.00)	$ (301,967,371.00)
Discounted projected proceeds	$ (248,865,793.28)	$ (259,230,052.41)	$ (269,116,522.64)	$ (278,718,618.57)	$ (287,590,643.93)
Projected administrative costs	$ 185,600,000.00	$ 185,600,000.00	$ 185,600,000.00	$ 185,600,000.00	$ 185,600,000.00
Discounted administrative costs	$ 183,798,058.25	$ 182,013,611.08	$ 180,246,488.65	$ 178,496,522.74	$ 176,763,546.79
Net costs	$ (65,067,735.03)	$ (77,216,441.33)	$ (88,870,034.00)	$ (100,222,095.83)	$ (110,827,097.14)

Initial model: High cost effectiveness

Costs	1	2	3	4	5	NPV
Cost of administration	$ 183,798,058.25	$ 182,013,611.08	$ 180,246,488.65	$ 178,496,522.74	$ 176,763,546.79	$ 901,318,227.51
Proceeds	$ (248,865,793.28)	$ (259,230,052.41)	$ (269,116,522.64)	$ (278,718,618.57)	$ (287,590,643.93)	$ (1,343,521,630.83)
Net cost	$ (65,067,735.03)	$ (77,216,441.33)	$ (88,870,034.00)	$ (100,222,095.83)	$ (110,827,097.14)	**$ (442,203,403.32)**
Emissions Reduction	0.025%	0.053%	0.079%	0.106%	0.132%	0.13%
Net cost per % PM2.5	$ (256,881,995,583.74)	$ (145,163,845,551.30)	$ (113,177,899,477.20)	$ (94,206,781,546.88)	$ (84,141,566,135.07)	**$ (335,727,343,465.40)**

<u>Major Assumptions</u>

1. Projected proceeds

My initial assumptions about the projected proceeds from TCI-P come from TCI's carbon market proceeds estimator. If I instead assume that proceeds will be 2/3 of the projected proceeds from the estimator, this alternative scores low on cost effectiveness.

Sensitivity 2: 2/3 projected proceeds, low cost effectiveness

Costs	1	2	3	4	5	NPV
Cost of administration	$ 183,798,058.25	$ 182,013,611.08	$ 180,246,488.65	$ 178,496,522.74	$ 176,763,546.79	$ 901,318,227.51
Proceeds	$ (165,910,528.85)	$ (172,820,034.94)	$ (179,411,015.10)	$ (185,812,412.38)	$ (191,727,095.95)	$ (895,681,087.22)
Net cost	$ 17,887,529.40	$ 9,193,576.14	$ 835,473.55	$ (7,315,889.64)	$ (14,963,549.16)	**$ 5,637,140.29**
Emissions Reduction	0.025%	0.053%	0.079%	0.106%	0.132%	0.13%
Net cost per % PM2.5	$ 70,618,475,436.08	$ 17,283,558,324.91	$ 1,063,993,535.47	$ (6,876,791,105.90)	$ (11,360,547,139.55)	**$ 4,279,800,020.75**

2. Administrative cost

In my initial analysis, I assume that the administrative cost of TCI-P will be $185.6 million per year, which is the amount the Commonwealth currently allocates for the administration of RGGI (HB 1301 Fiscal Impact Statement, 2022). If I assume that the administrative cost of TCI-P will be 50% greater than the current administrative cost of RGGI, then the cost effectiveness of this alternative becomes low.

Sensitivity 3: 1.5x administrative cost, low cost effectiveness

Costs	1	2	3	4	5	NPV
Cost of administration	$ 275,697,087.38	$ 273,020,416.63	$ 270,369,732.97	$ 267,744,784.11	$ 265,145,320.18	$ 1,351,977,341.27
Proceeds	$ (248,865,793.28)	$ (259,230,052.41)	$ (269,116,522.64)	$ (278,718,618.57)	$ (287,590,643.93)	$ (1,343,521,630.83)
Net cost	$ 26,831,294.10	$ 13,790,364.21	$ 1,253,210.33	$ (10,973,834.46)	$ (22,445,323.74)	**$ 8,455,710.44**
Emissions Reduction	0.025%	0.053%	0.079%	0.106%	0.132%	0.13%
Net cost per % PM2.5	$ 105,927,713,154.13	$ 25,925,337,487.36	$ 1,595,990,303.20	$ (10,315,186,658.85)	$ (17,040,820,709.32)	**$ 6,419,700,031.13**

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