An Initial Assessment of Vermont's Progress in Equitably Electrifying Transportation to Meet Climate Goals

By Ellery Curtis

August 2021

Ellery Curtis is a rising Senior at Dartmouth College majoring in Government and Environmental Policy. This report is the result of a 10-week Summer Internship Program designed and led by EAN Senior Fellow Christine Donovan.

Abstract

As Vermont grapples with the dual issues of high greenhouse gas emissions from the transportation sector and inequitable transportation burdens, greater electric vehicle (EV) adoption will undoubtedly be a part of state policy solutions. However, similar to other technologies and products in the early stage of market adoption, EV distribution remains concentrated in the state's more urban and affluent areas. This report:

- Provides an overview of Vermont's progress electrifying transportation to meet climate goals;
- Explains the importance of factoring transportation equity and justice into future program design and implementation;
- Examines the extent to which state-funded EV incentive programs are (or are not) currently reaching those most in need; and
- Recommends new research, data collection, and analysis that would further embed equity and justice in future development and evaluation in Vermont.

Initial spatial analysis and linear regression models conducted for this report indicate that the uptake of program funding for EVs is largely concentrated in geographic areas of the state that do not, generally, include those communities with the highest transportation burdens. With this in mind, the report recommends that future program implementation be enhanced to more effectively reach the highest burdened communities. It is also recommended that data collection and program evaluation be improved to effectively monitor the success in providing those most burdened with increased access to affordable and clean electric vehicles.

I. An Overview of Vermont's Progress Electrifying Transportation to Meet Climate Goals

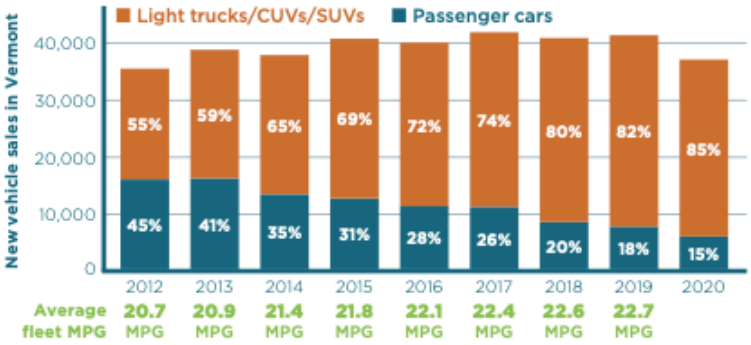
The Global Warming Solutions Act (GWSA) passed in Vermont in 2020 provides an important opportunity to both decarbonize our economy and prioritize equity in the process. The GWSA requires the state to reduce greenhouse gas emissions by 26% below 2005 levels by 2025, 40% below 1990 levels by 2030, and 80% below 1990 levels by 2050. The Act also directs the organization of a statewide Climate Council responsible for overseeing development and implementation of a statewide Climate Action Plan for meeting the statutory targets. The Plan must also include specific strategies "to minimize negative impacts on marginalized and rural communities and upon individuals with low and moderate income," which is the closest Vermont has come to developing an environmental justice policy.[1]

While Vermont GHG emissions have been trending downwards since their peak in 2004, the transportation sector remains the largest emitter, accounting for 40% of statewide emissions.[2] It also remains one of the hardest sectors to decarbonize due to the state's rural nature, historical settlement patterns, and reliance on fossil-fuels for transportation. The vehicle miles traveled (VMT) per capita in Vermont is higher than the national average as well as those of

[1] Vermont Global Warming Solutions Act of 2020
[2] 2020 Annual Energy Report, 2020

neighboring states and has risen 5% between 2014 and 2017.[3] Data from the 2015-2019 American Community Survey (ACS) five-year estimates also show an increase in single occupancy vehicle commuting since 2009.[4] Further compounding Vermont's high transportation emissions is increasing consumer preferences for light trucks and larger passenger cars. Figure 1 shows the increase in new car sales that are SUVs, crossovers, or light trucks, compared to passenger cars since 2012, which has limited the gains that could otherwise be achieved from improving fuel efficiency standards.[5]

Figure 1: New Vehicle Sales in Vermont by Type

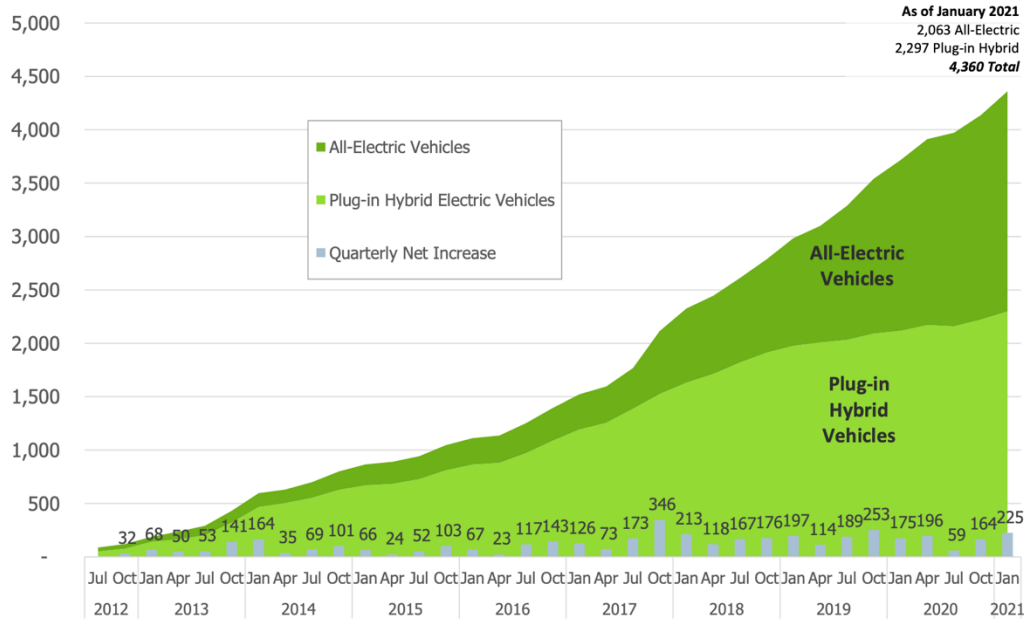


Sources: Sales: VADA, 2021. Fleet MPG: UVM/VTrans, Transportation Energy Profile, 2019. Note: Fleet MPG is average combined MPG (avg city and avg highway).

1. Current EV Use in Vermont

As of January 2021, Vermont had 4,360 all-electric and plug-in hybrid vehicles registered in 90% of zip codes. Figure 2 shows the increase in EV adoption since 2013. [6] Vermont outpaces other New England states and ranks 5th in the country in per capita EV registrations.[7] Vermont also ranks first in the nation for charging infrastructure per capita.[8] Figure 3 shows the distribution

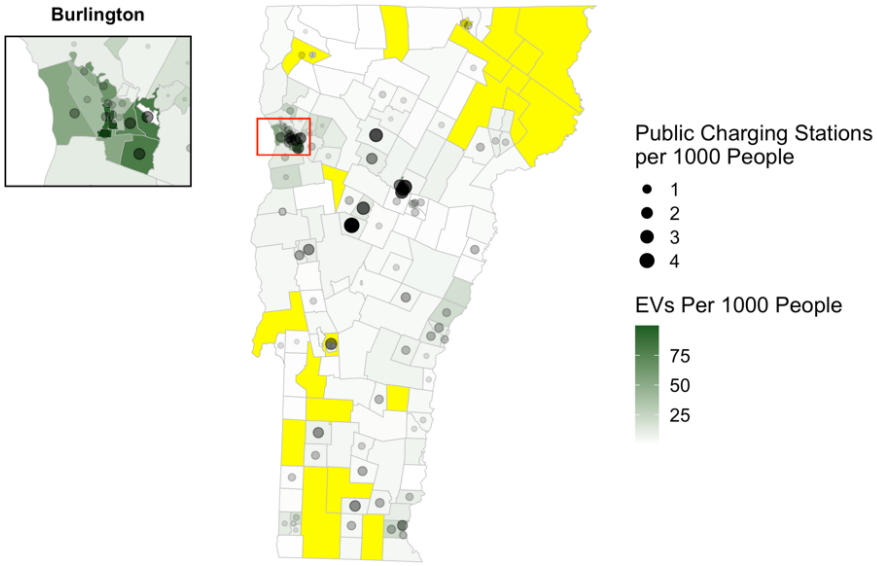
Figure 2: Vermont Electric Vehicle Registrations



[3] Vermont Greenhouse Gas Emissions Inventory and Forecast, 2021
[4] VT Transportation Energy Profile, 2019
[5] 2020 Annual Energy Report, 2020
[6] Vermont Electric Vehicle Registration Trends
[7] Ibid.
[8] Howard et al., 2021

of EV registrations per capita as of 2020, overlaid with the current distribution of available public charging infrastructure. The areas of highest adoption also have the infrastructure to support the increased electrification. While the causal relationship can't be defined between charging and adoption can't be defined here, it is clear that census tracts with no charging infrastructure are not home to any EVs.

Figure 3: EV and PHEV Vehicles Per Capita



Despite transportation electrification progress the state must ramp up adoption rapidly to meet the GWSA requirements. The EAN transportation electrification pathway from the EAN Emissions Reduction model anticipates that meeting greenhouse gas reductions specified in the GWSA could require a ramping rate of 1441% by 2025 (6,145 vehicles added yearly) and 3920.1% by 2030 (15,397 vehicles added yearly, although the EAN pathways model is not prescriptive and the actual unite measurements are dependent on the scaling of other decarbonization measures).[9] If the state manages to meet the level of EV penetration needed given the GHG reduction requirements, this could pose serious equity implications for those unable to access or afford EVs. For example, in the 2019 Supplemental Report to the Legislature, the Vermont Public Utility Commission recommended that the state *not* impose a per-kWh energy efficiency fee on electric vehicle charging (akin to the per-gallon gasoline tax).[10] At our current stage of EV adoption, this decision is intended to continue to encourage the growing EV market. But if the gas tax base loses 120,000 drivers by 2030, the burden of transportation infrastructure will fall on those who cannot access or afford EVs. Thus the anticipated increase in transportation electrification over the next decade (and beyond) will require dedicated policy initiatives to ensure that transportation equity and justice are addressed in the transition.

2. Barriers to EV Use

Many barriers to equitable EV uptake exist. While the focus of this report is on the evaluation of incentive programs, recognition of the current barriers to EV adoption by low- and moderate-income households is important in order to develop performance metrics. Examples of key barriers include:

[9] EAN Emissions Pathways Reduction Model, 2021
[10] Supplemental Electric Vehicle Report, 2019

- The generally higher upfront price of EVs (before incentives) compared to new and used gasoline vehicles;
- Limited or no access to EV charging, especially for those in rural locations, those living in multi-family housing, and those who cannot afford a home charger;
- Range anxiety: higher automobile dependence in rural areas increases range anxiety issues. Vermont weather conditions compound this concern in the winter. Households with only one vehicle are especially susceptible to range anxiety as a barrier to purchase as they do not have a second vehicle to rely on for longer trips.
- Lack of inventory availability: Weather also factors into consumer preferences, as many Vermonters prefer to drive four-wheel drive vehicles, of which there are fewer EV or fuel-efficient model options available than two-wheel drive EVs or internal combustion engine (ICE) counterparts.[11] About two thirds of sales in the state are used vehicles. The used EV market is growing but largely not available at the scale needed for widespread adoption. [12]

Finally, a lack of transportation data in the state hinders the understanding of EV adoption that would better inform policymaking. The concluding remarks of the Transportation Research Board of the National Academies 2nd Strategic Highway Research Program Study on GHG mitigation in decision making summarized this barrier well: "By far, and not surprisingly, most of the research on GHG emissions reduction strategies has focused on metropolitan areas or at the national and state levels … very little attention has been given to nonurban areas."[13] This is not an issue endemic to Vermont: The International Council on Clean Transportation reported in their Transportation Electrification Scorecard that they were unable to evaluate whether state policies are supporting equitable access to EVs and EV charging equipment" due to a lack of data collection, and argue that "understanding such factors as whether residents of marginalized communities have access to and are using charging facilities in their neighborhoods will be important to measuring the success of equitable state and local EV infrastructure investments and policies."[14] Vermont is a small and rural state dealing with limited funding. Data collection at the intersection of equity and transportation often does not get the attention needed in favor of investing funds directly into programs implementation.

3. Current EV Policies and Programs in Vermont

Vermont has begun addressing the range of barriers to increased EV use noted above. For example, legislation passed in 2019 allocated $1.1 million of Volkswagen Settlement Funds to an EV incentive program to encourage the purchase or lease of new plug-in electric vehicles (PEVs), which is inclusive of all-electric vehicles (AEVs) as well as plug-in hybrid electric vehicles (PHEVs).[15] In November of 2020, the state reauthorized the program with an additional

[11] Samantha Hurt, Capstone, in conversation with the author, 12 July 2021
[12] Roberts, 2019
[13] Rowangould, 2021
[14] Howard et al., 2021
[15] Act No. 59 (H.529)

$950,000 in dedicated funding, which lasted until May of 2021, at which time VTrans sourced an additional $500,000. In June of 2021, the state allocated $2.7 million more to the program.

Eligibility was initially determined using Vermont's Weatherization Assistance Program standards. Originally, households with low and moderate income at or below 160% of the state's prior five-year average Median Household Income level were eligible. In 2020, the program shifted to an adjusted gross income (AGI) eligibility threshold scaled by county. Vermont currently offers the following incentives:

- Households making $50,000 or less are eligible to receive $3,000 for a plug-in hybrid electric vehicle and $4,000 for an all-electric vehicle.
- Households making $50-100,000 (or $125,000 for joint filers) are eligible to receive $1,500 and $2,500 respectively.

Eligible vehicles include all new PEVs with a base manufacturer's suggested retail price (MSRP) under $40,000. Incentives can be combined with federal and utility programs. The federal government offers $2,500 to $7,500 tax credits for new vehicles, scaled based on battery size and limited by original equipment management (OEM) production, meaning Tesla and GM EVs are no longer eligible. The three largest utilities in Vermont (GMP, BED, and VEC) offer varying levels of additional EV incentives with increased amounts for income-eligible customers. Green Mountain Power (GMP) leads the way with a rebate up to $2,500 and a free Level 2 charger with each EV purchase.[16] While data from these programs were unavailable for this report, it is important to note that state incentives represent only a portion of the total financial support available to consumers interested in purchasing an EV.

The state of Vermont also funds MileageSmart, a separate incentive program that offers 25% off of a high fuel-efficiency vehicle (40mpg or higher) up to $5,000 to Vermonters at or below the 80% AGI based on household size. Since the program's re-launch in October of 2020, 93 incentives have been distributed and more than 600 Vermonters have filled out an interest form.[17] However, the program faces several challenges to uptake, namely a lack of affordable inventory of more efficient vehicles that fit the profile of consumer preferences in Vermont. According to Samantha Hurt, program administrator at Capstone Community Action, the non-profit responsible for the program's administration,

> "In Vermont, a lot of folks, understandably so, would prefer an all-wheel drive vehicle. And right now, almost every all-wheel drive vehicle I find that is eligible is $20,000 to $30,000. For most folks, that is not an option at all. Inventory definitely plays a role in the success of the program, and it is unfortunate we cannot change that."

[16] The Burlington Electric Coop offers $1800 rebate for an AEV, $1,500 for a new PHEV, and $800 for a used electric car. Moderate income purchasers receive an additional $600 or $400 incentive based on PEV type. Vermont Electric Coop (VEC) offers a $500 bill credit for AEVs and $250 for PHEVs with an added $250 for low-income participants.

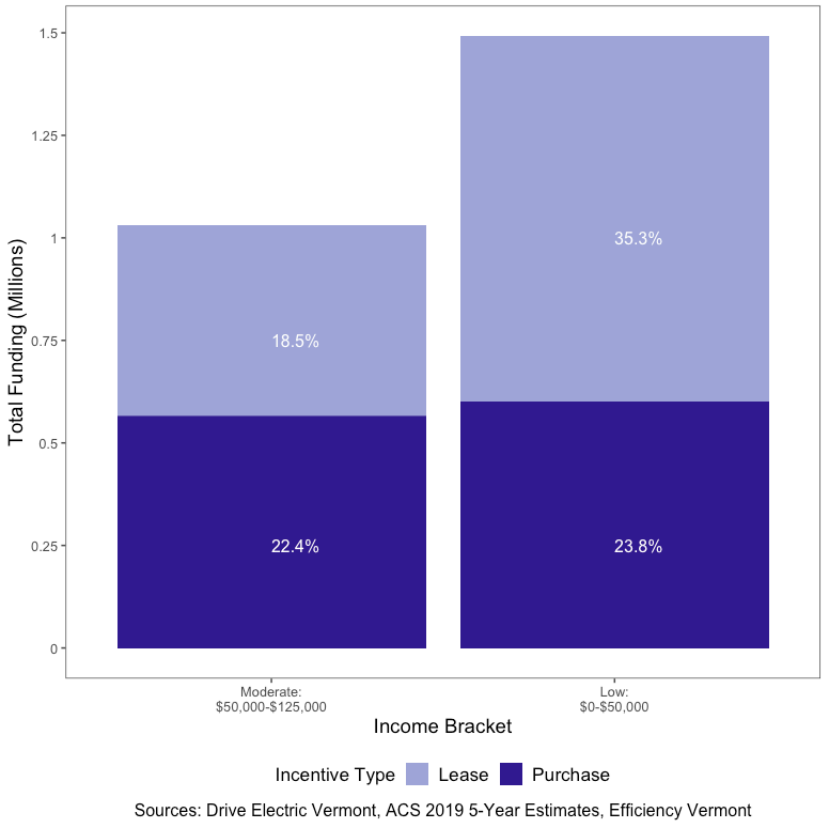
[17] Samantha Hurt, Capstone, in conversation with the author. 12 July 2021

Nonetheless, MileageSmart is meant to fill an important access gap for consumers who might face barriers to buying EVs but want to drive move more efficiently.

4. Current EV Program Evaluation in Vermont

The MileageSmart Program purposely does not require collection of demographic data, as their goal is to make the process as easy as possible for the applicants and avoid creating a further barrier for participants who might be uncomfortable answering questions about income, ethnicity, etc.[18] However, they recently began to include a voluntary demographics questionnaire in the application, upon instruction from VTrans. Any demographics data collected is confidential and does not affect applicant eligibility. MileageSmart also sends out an exit survey to participants that includes questions on satisfaction with the application process, experience with dealer and lender, and where the participant heard of the program.[19]
The PEV Incentive Program currently evaluates quarterly spending by type of incentive and income classification. As of July 9th, 2021, low-income households received 44% of the number of incentives and 59% of total spending compared to the moderate-income households. Figure 4 displays the percentages of funding broken down by incentive type as well as income. The only demographic data collected is on age and gender, gleaned from registration licenses. According to a VEIC memorandum included in the 2021 "Report on Vermont's Statewide Vehicle Incentive Programs", "The State PEV incentive program application process has not collected data on socio-economic characteristics of program beneficiaries to-date as the limited funding has been directed to maximize funds available for incentives rather than program evaluation activities." Also included in this memo is the geographic breakdown of incentive funds per 10,000 people by county. Chittenden and Washington County received the largest quantity and highest per capita amount respectively, while Essex County received the fewest on both metrics. The memo faults geographic disparities in funding on differences in income, local awareness of EVS, availability of preferred vehicle type, and

Figure 4: Incentive Type by Income



Sources: Drive Electric Vermont, ACS 2019 5-Year Estimates, Efficiency Vermont

[18] Ibid.
[19] Ibid.

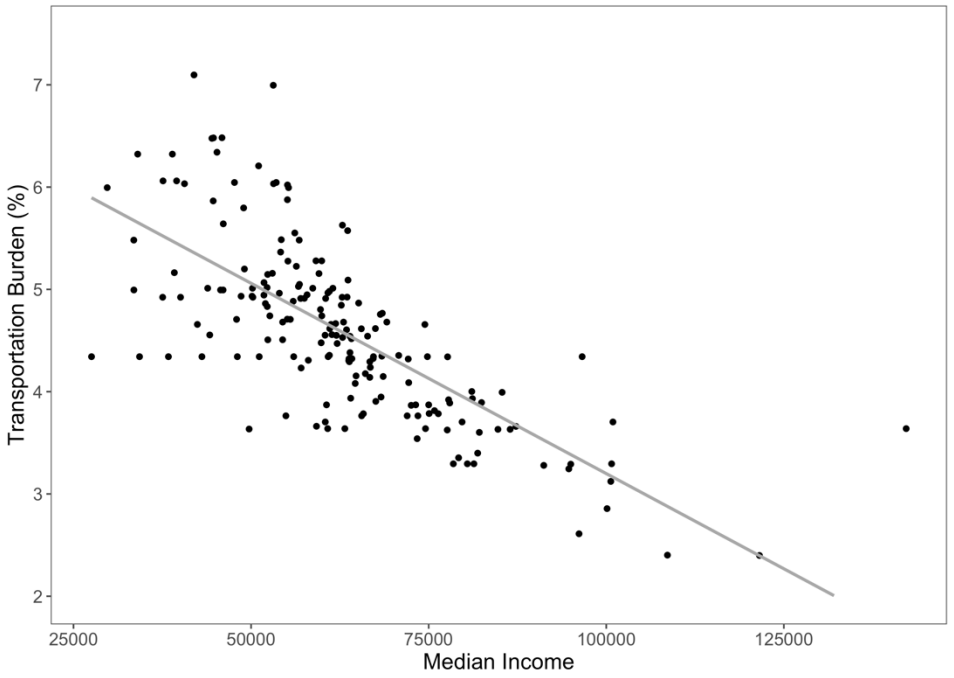
maintenance service availability across regions. To better understand the demographics and mindsets of participants, the UVM Transportation Research Center and VTrans have plans to collaborate on a short questionnaire to be included in the application "to better address equity and environmental justice considerations and to improve overall program effectiveness" as well as a post-participation voluntary survey to evaluate program design.[20] Both are pending funding.

II. The Importance of Factoring in Equity and Justice When Scaling Up EV Adoption

There are a variety of equity and justice issues that are important to understand and consider when planning future transportation initiatives intended to reduce GHG emissions.

Transportation equity is broadly concerned with the question of who receives the benefits and who is saddled by any burdens resulting from transportation infrastructure or planning decisions. Transportation accounts for the largest portion of total energy costs for Vermonters, and around 7% of households in the state lack access to a household vehicle mostly due to cost.[21] As noted in the EAN Transportation Burden Study completed in 2020, lower income households in Vermont also have a higher transportation burden than other households, meaning they spend a larger percentage of their income on transportation costs.[22] Figure 5 depicts the transportation burden by census tract median income in Vermont. Rural Vermonters face the added hardship of fewer public transportation options and further distances to travel than those living in more urban areas. In the Northeastern United States at the household level in, the lowest earning households spend up to five times as much of their incomes on transportation than do their higher income counterparts. The latter groups also drive older cars and thus have higher upkeep costs. [23]

Figure 5: 2019 Transportation Burden by Median Income of VT Census Tract



Source: Efficiency Vermont 2019 Energy Burden Report.

[20] Roberts, 2020
[21] EAN 2021 Annual Progress Report
[22] Ibid.
[23] Ibid.

Transportation justice is defined to be the achievement of a transportation system in which no individual or community is "disadvantaged by a lack of access to the [transportation] opportunities they need to lead a meaningful and dignified life."[24] A transition to transportation justice entails a comprehensive measurement of the underlying social structures that lead to disparities in transportation access and outcomes. Applying this justice framework to the Vermont transportation sector requires examining racial disparities beyond just questions of income. According to survey work done by Dr. Bindu Pannikar and the Rubenstein School of Environment and Natural Resources of the University of Vermont, black, indigenous, and people of color (BIPOC) in Vermont are twice more likely than white respondents to report:

- Lack of access to transportation;
- Lack of vehicle ownership;
- Other non-transportation related needs like food insecurity and lack of medical care access,

And are three times as likely to:

- Rely on public transportation;
- Have trouble paying electricity bills;
- Go hungry in a month, and;
- To contract Lyme disease.[25]

Given these compounding stressors causing disparate impacts across racial lines, an examination of EV incentive programming using more indicators than simply income is needed. This report uses the Vermont Environmental Disparity Index (VT EDI) to do so. The EDI is a tool developed by Panikkar and Qing Ren of the Rubenstein School in conjunction with the VT Department of Environmental Conservation. The VT EDI combines environmental exposure metrics with health risk factors and the VT Social Vulnerability Index to comprehensively identify communities that are the "most susceptible environmental hazards and most vulnerable to the modifying effect of socio-economic factors."[26] As Vermont prepares to significantly scale up investment in GHG reduction strategies, it is important to understand the geographic distribution of historically disadvantaged communities in order to direct funding to those most in need. Certain states have established funding floors within their climate-related statutes that must be directed towards communities identified by similar tools. The VT EDI was used for this report because of the intersectional nature of burdens on people's lived experiences, and the positive local health and economic impacts that EV adoption has the potential to provide to overburdened communities.

[24] Karner et al., 2020
[25] Pannikar, 2021.
[26] Vermont Environmental Disparity Index.

As EVs improve in battery technology and costs come down, they offer a pathway to reduce both carbon emissions and transportation inequities. Several studies show potential reductions in purchase, maintenance, and fuel costs for consumers switching to EVs and fuel-efficient vehicles, freeing household funds to spend on other essentials and savings.[27] In Vermont, these savings quantified equate to $2,837 annually for rural households and $1,903 for urban, adding up to $21,729 and $26,756 lifetime savings for both groups respectively.[28] EVs can also mitigate local air pollution and reduce health and environmental externalities across the state, which cost the state $347 million annually.[29]

However, electric vehicles also pose equity concerns for low-income individuals. EVs are an early-stage technology in Vermont and there is not yet a robust supply of lower cost, used EVs. According to the International Council on Clean Transportation, EVs will meet upfront price parity with average vehicle sales in low-income demographics by 2029.[30] Thus there is some question about the efficacy of aggressively promoting EV leases and purchases now rather than in the future as costs come down and technology improves. Karen Glitman of the Center of Sustainable Energy (CSE) discussed this idea an interview conducted for this report,

> "New technologies often start with more affluent consumers. New EVs, like all new automobiles, are being adopted by those with greater resources. Wealthier people spending their money on a new technology, whether EVs or solar, can help drive down the cost and accelerate the adoption of the things that we want to see mass adoption of. This is the beginning of the diffusion curve to mass market adoption to help meet the climate imperative."

Regardless, EVs still present a cost-saving opportunity for all income groups. It thus remains important to evaluate incentive programs on their success in creating more accessible adoption. As an example, a number of studies examining recipient characteristics of California's Clean Vehicle Rebate Project (CVRP) showed that the initial design mainly benefited wealthy, white Californians who might have purchased EVs regardless of the subsidy.[31] These evaluations resulted in program design adjustment. Effective program evaluation not only hold the programs accountable to effective implementation but also aid in understanding how disparities in car ownership perpetuate transportation justice issues and where opportunities exist to improve access to affordable EV for those most burdened by energy and transportation costs.

III. EV Transportation Equity and Justice in State Incentive Programs and an Initial Analysis of Vermont's Progress

1. Literature Review

[27] Slowik and Nicholas 2021; Greene and Welch 2017; Kerman, 2019; Lutsey & Nicholas, 2019; Propfe et al., 2012.
[28] Union of Concerned Scientists, Clean Transportation Strategies for Rural Communities in the Northeast and Mid-Atlantic States, 2020.
[29] "Transportation Electrification in the State," Presentation by Vermont Energy Future Initiative, August 2019.
[30] Bauer et al., 2021
[31] Rubin and St-Louis, 2016; Searle et al., 2016

A literature review on the factors influencing the equitable and just adoption of electric vehicles conducted for this report revealed an extensive body of work on this topic.

Several studies focused on the role of state and local policy in EV adoption. Narasimhan and Johnson examined the impact of incentives, charging availability, and receptive demographics to determine that tax incentives and charging infrastructure significantly and positively influence per capita plug-in electric vehicle purchases.[32] De Shazo et al. further analyzed the impact of incentives by testing different theoretical alternatives to the CVRP to find that an aggressive increase in incentives with a price cap would increase allocative equity and save money.[33] Several other studies confirmed the importance of well-designed incentives with the caveat that policy is only a part of the puzzle; fuel prices, environmentalism, vehicle availability, vehicle miles traveled, education, and weather also affect purchase decisions.[34]

A parallel body of literature examined the consumer profiles of EV adopters in the US. Most of this study happened in California where uptake is the highest and the CSE makes individual-level data transparent and accessible. There is wide consensus that the early adopters of clean vehicles are high-income, mostly male and middle aged with a university degree.[35] Lee et al. studied heterogeneity amongst early EV adopters using survey data from EV consumers in California. They found that high income families buy the most PEVs, while the mid/high income, young families' share is increasing over time. They also used a Bass diffusion model to find that the consumer clusters of mid/high-income older families, mid/high-income young families, and middle-income renters have potential for increasing adoption by 2030 if sufficient purchase incentives and charging infrastructure support are offered.

However, relatively little attention has been paid to the adoption of the technology in communities identified as environmentally burdened, although the practice is growing. Guo and Kantou used rebate numbers, amounts, median income, and disadvantaged community (DAC) indicators to conduct horizontal and vertical equity analyses. They found that the most rebates are concentrated in a small number of census tracts. Over time, however, disparities decreased as the market matured and policy design improved (namely instituting an income-cap and increasing the low to middle income rebate amounts). Canepa et al. examined PEV adoption more generally in disadvantaged communities and found that new and used PEV purchases in disadvantaged communities account for a disproportionately small amount of the total. PEV owners that live in disadvantaged communities have higher incomes, are higher educated, and fewer are home-renters than their surrounding community.[36] Rubin and St. Louis also studied CVRP incentive allocation by census tract and conduct an ordinary least squares and negative binomial regression modeling using race-ethnicity, income, and socioeconomic and environmental disadvantage data. They found that wealthier tracts received more rebates

[32] Narassimhan and Johnson, 2018
[33] De Shazo et al., 2017
[34] Jenn et al., 2018, Münzel et al., 2019; Langbroek et al., 2016; Tal and Nicholas 2017; Vergis and Chen, 2015
[35] Hardman et al.; Lee et al., 2019
[36] Canepa et al., 2019

while tracts with higher proportions of Hispanic and African American residents received fewer rebates even with income controls.[37] Finally, Johnson and Williams 2017 used CVRP participant survey data to examine whether participating consumers would have purchased their vehicle without the rebate. Their findings showed significant differences in distribution of consumers who characterized their incentives as essential across the state and demographic groups. Specifically, they found a positive association between rebate influence and identification with a nonwhite ethnicity or as male, reinforcing the need to design incentive programs through a transportation justice lens.[38]

2. Research Questions for the Quantitative Analysis of Vermont's PEV Incentive Program

Lessons from the CVRP studies were formative in developing the theoretical basis for the initial equity analysis that this report provides. Based on the questions asked and the results discussed in the above review of the literature as well as the barriers to equitable and just EV uptake in Vermont, this report seeks to determine:

1. Whether state incentives are reaching those most in need by quantifying the relationship between PEV incentive allocation and the socioeconomic characteristics of Vermont census tracts.
2. If the MileageSmart program is doing its intended job of filling gaps for people who might not be able to afford an EV or have access to charging?
3. What can be learned from quantitative analysis in other states in order to better assess and achieve equity in future Vermont EV offerings?

It is hypothesized that although incentives are reaching low-income households, their distribution is not geographically equitable given disparities in charging infrastructure investments and outreach.

3. Data and Methodology

To conduct this analysis, seven different datasets were joined by 2010 census tract geographic identifiers, or GEOIDs. There are 183 census tracts in Vermont, some of which enclose multiple towns and some of which only cover an area within a city, but each contain anywhere from 4,000 to 8.000 residents. Each dataset and its source are explained in the list below:

1. **Demographic data** from the US Census Bureau 2015-2019 5-year American Community Survey and access through Social Explorer and IPUMs. Variables included population and population density, median income and age, race, education levels, commuting patterns, and vehicle availability.
2. **VT Environmental Disparity Index (EDI)** data from Qing Ren, co-creator of the Index and Gund Fellow at the University of Vermont. The top 25% census tracts scored by the EDI

[37] Rubin and St-Louis, 2016
[38] Johnson and Williams, 2017

were pulled into a dummy variable to represent disadvantaged communities using the same criteria that California uses to define DACs.

3. **Transportation burden data** from Efficiency Vermont's 2019 Energy Burden Report, found by dividing average transportation spending by Median Household Income. This dataset was provided at the town level. Large towns with multiple census tracts were separated into multiple GEOIDs with the same burden applied to each GEOID. Smaller towns that together make up one census tract were aggregated, and their burden was averaged.
4. The **Vermont Plug-In Electric Vehicle Incentive Program data** retrieved through Dave Roberts and Drive Electric Vermont after an approval process with the Vermont Agency of Transportation. The dataset included 861 incentives distributed since December of 2019. Because incentive amounts varied by income, it was possible to determine whether the applicant was low or middle income based on how much funding they received. To determine incentive distribution per number of eligible households, the upper income bound of $125,000 was used for joint filers, and the number of households within each income bracket per census tract was then used as the denominator.
5. **MileageSmart Incentive Program data** provided by Samantha Hurt of Capstone Community Action. This dataset included 93 observations of incentives distributed as of July 8, 2021.[39] MileageSmart incentives were given on the town level. For census tracts that had multiple towns within it, the incentives were aggregated, and for large towns that had multiple census tracts within one town boundary, the incentives were divided evenly, which was a limitation to this approach. To determine incentive amount per eligibility, average household size per town and the 2015 - 2019 ACS income data were used to estimate the number of eligible people under the eligibility threshold from the MileageSmart Plus Website.
6. **The locations of public charging infrastructure** from the Alternative Fuels Data Center. The data included 302 stations as of July 8th, 2021 given by town, so similar to the process with the MileageSmart Incentive Program dataset, for census tracts that had multiple towns within it, the number of chargers were aggregated, and for large towns that had multiple census tracts within one town boundary, the charging stations were divided evenly.
7. **Total EVs in Vermont** from the EAN Community Dashboard. This data was aggregated from Drive Electric Vermont, the Vermont Agency of Natural Resources (ANR) and the Vermont Department of Motor Vehicles (DMV). Only data until January 2019 was available.

To begin to study the relationship between incentives and census tract demographics and infrastructure, I first visualized and compared the geographic distribution of the variables. The dependent variables of interest are the rate of PEV or MileageSmart Incentives received per 1,000 households per census tract. The independent variables were chosen based on the

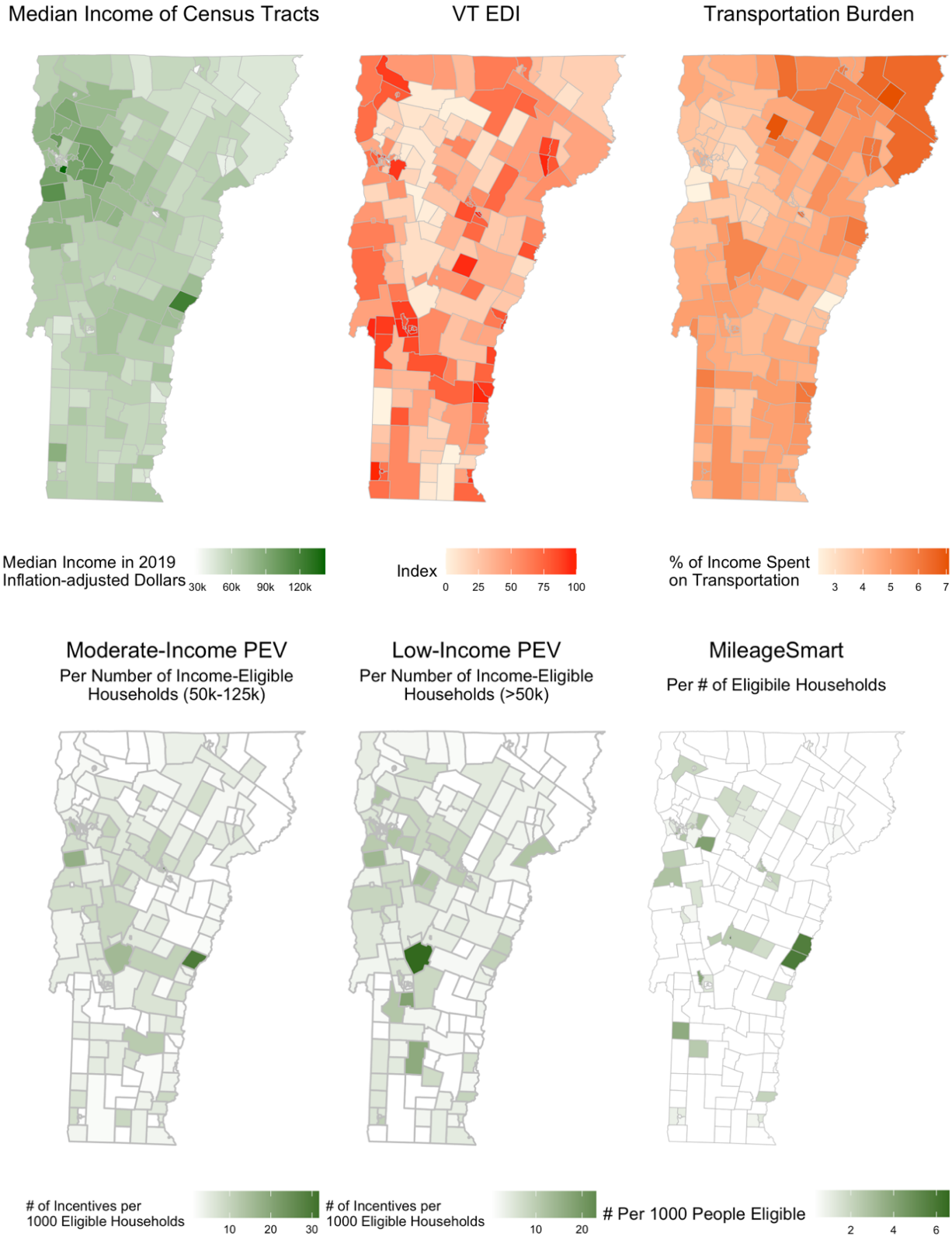
[39] This number is now 120 as of 8/17/21.

literature review as well as the barriers and accessibility issues identified in Vermont, as well as initial correlation testing. I then developed several Ordinary Least Square (OLS) regression models to statistically examine the relationship between incentive rates and socio-demographic variables by census tract.

4. Results and Discussion

The goal of the analysis was to examine the distribution of state incentive funding to determine whether the most burdened areas of the state are taking advantage of the Electric Vehicle Incentive programs available in Vermont (as of 2020). This is valuable because it assesses equity and justice considerations from a second lens, beyond the simple measure of incentive amount per income bracket (discussed above). An initial look into the geospatial patterns of incentive funding in Figure 6 shows that across all incentive types, the funding is largely missing the geographic locations with the highest transportation burden and the highest environmental burden. **15.6% of PEV incentive funding went to the highest quintile of transportation burden while 39.5% went to those census tracts in the lowest quintile of transportation Burden.**

Figure 6: Vermont Demographiccs beyond Income Compared to Incentive By Distribution Type



Sources: 1. ACS 2019 5-Year Estimates; 2. Qing Ren, UVM; 3. Efficiency Vermont 2019 Energy Burden Report; 4. Drive Electric Vermont, ACS 2019 5-Year Estimates; 5. IBID; 6. Samantha Hurt Capstone Community Action

Figure 7: Top 10 Census Tracts by Incentive Amount

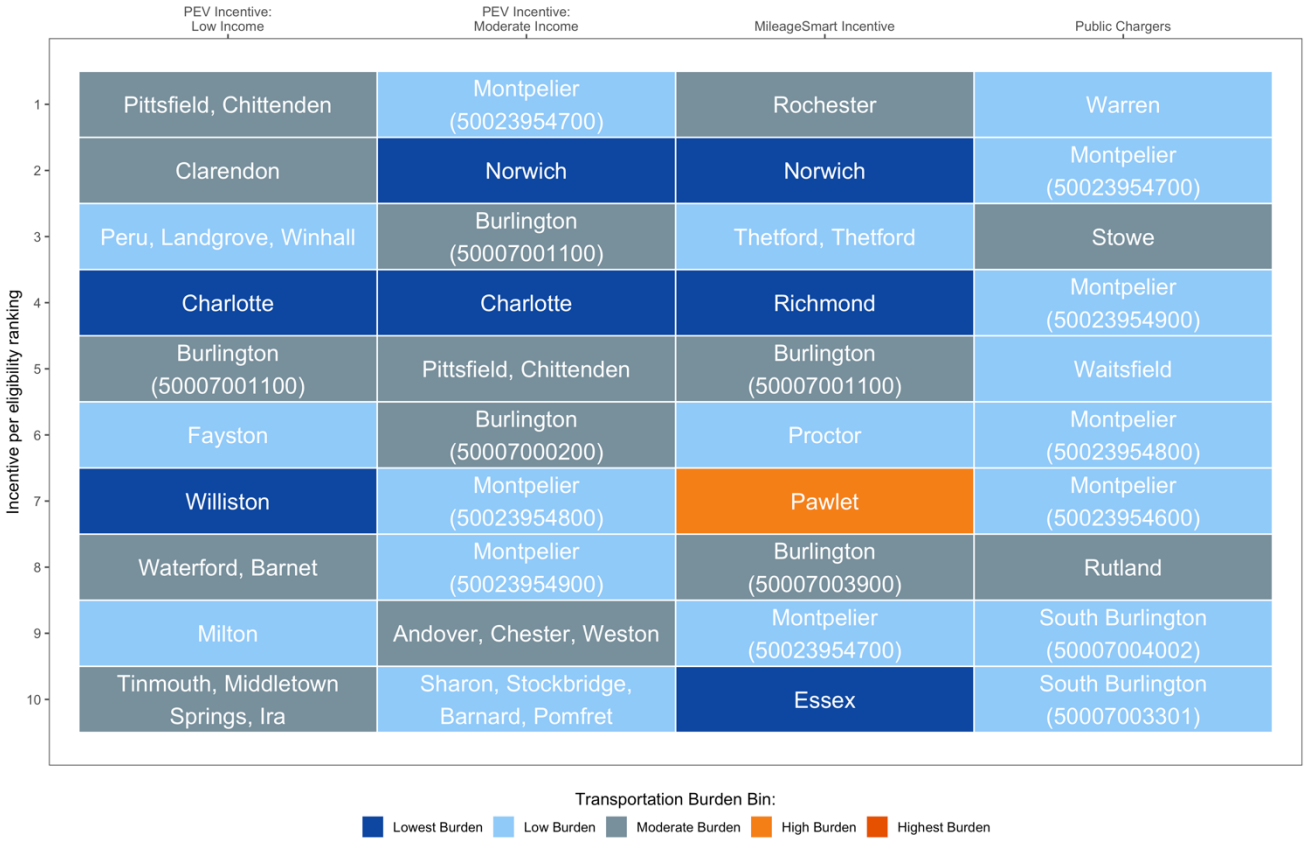


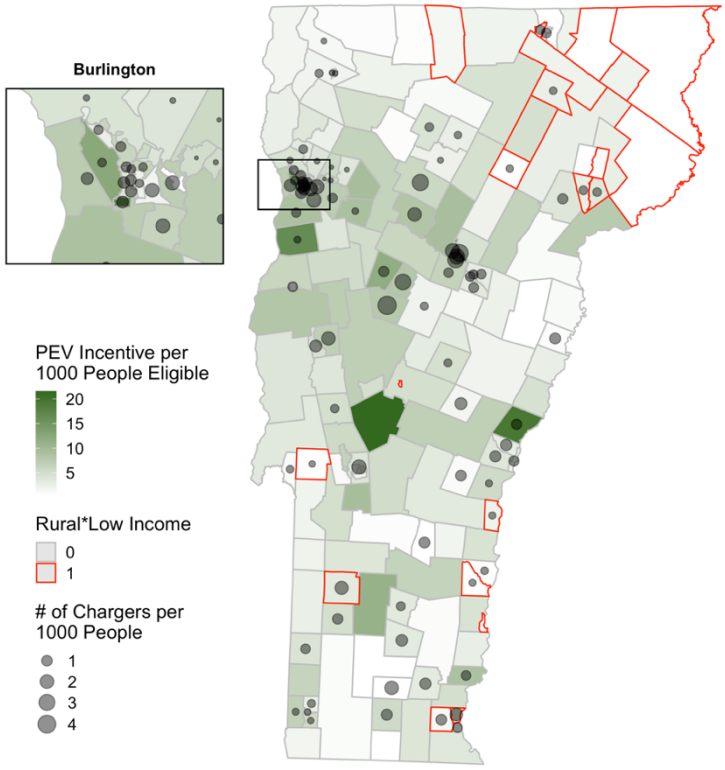
Figure 7 shows a deeper look into the relationship between incentive and transportation burden. The town of Pawlet is the only High Burdened tract that received a relatively high amount of funding from the MileageSmart Program. Because transportation burden is higher for rural Vermonters, this prompted an examination of the rural-urban discrepancy in incentive allocation. **Urban census tracts (defined by the Census Bureau as areas that have a population density of at least 1,000 people per square mile), received 31% of the number of incentives and 24% of total funding although only 19.6% of census tracts in the state are considered urban.**[40] Visualized in Figure 8, **urban areas also have more public charging infrastructure available than rural: .71 public chargers per capita in urban areas compared to .43 chargers per capital in rural areas.**

These geographic disparities in incentive and infrastructure allocation are in spite of the fact that a majority of total statewide funding went to low-income recipients, as mentioned above. This highlights the importance of multiple lenses of analysis. Once evaluating on a more granular level than low versus moderate incentive distribution, the equity outcomes of the incentive programs become clearer and more transparent. **The reality that low-income people are getting the majority of incentive funding, but only in certain advantaged areas, prompts several possible explanations that warrant greater attention in the future:**

[40] "The Urban and Rural Classifications." Geographic Areas Reference Manual. United States Census Bureau.

1. Low-income people may see charging infrastructure, existing EV's, or EV dealerships and service stations around them and become aware of the EV option. Guo and Kontou find this "neighboring effect" in their study of geographic distribution of EV incentives and describe it like this: "communities with lower median income or disadvantaged receive higher rebate amount when these are geographic neighbors to clusters characterized as high income and high rebate amount receivers."[41]
2. Low-income people in more urban parts of the state may feel more comfortable about switching to electric vehicles because they have more transportation options available and already travel fewer miles.
3. Dealerships in rural areas may have been slower to add EV inventory and market the incentives available, and autobody shops may have been slower to offer EV-specific services.

Figure 8: Incentives and Charging in Rural*Low Income Tracts



These questions warrant further study. Confined to census tracts for this analysis, however, an attempt was made to understand which independent variables across census tracts predict high rates of PEV incentive and MileageSmart uptake. **In other words, if incentive funding isn't reaching the most rural and highest transportation burdened communities, where is it going?** Taking census tracts as individuals, I developed two multivariate regression models to study PEV incentive and MileageSmart uptake separately. A coefficient table and plot are presented in Appendix 1 to show the exact results of the models. The adjusted R-squared (model fit)

[41] Guo and Kontou, 2021

remained low for both models due to the many factors influencing incentive participation decisions (some of which were unable to be captured by the accessible data). However, several takeaways can still be gleaned from the results.

- **The availability of public charging infrastructure proved to have statistically significant results for PEV incentives**. For every charging station per 1,000 people added, the number of incentives per 1,000 people increased by .24, which is significant at the 95% confidence level.
- **The percentage of higher education was also statistically significant at the 99% confidence level for both incentive types and proved a greater factor for PEV incentives**. A one percentage point increase in higher education led to an additional 2.7 PEV incentives per 1,000 people. Median Age and Income were also statistically significant at the 90% confidence level for PEV incentive model but substantively very small.
- **The percentage of households renting had a negative effect on MileageSmart uptake, significant at the 95% level**.

5. Limitations of the Analysis and Areas for Future Research

Analysis completed for this report was limited in several ways. Most importantly, this study used geographic, census level data. While geographic data is an important method to be included in equity and justice analyses, such analyses should ideally start at the individual level in order to accurately characterize the demographics of PEV incentive users. However, incentive recipients are not currently required or asked to fill out participation surveys, and privacy concerns have precluded publicly available household-level data. Data was only available by census tract, which often include a range of demographics and socioeconomic levels. Incentive recipients in a census tract may not be representative of the overall demographics of that census tract or the broader community.

It is also important to note that incentives are distributed by demand and are only available for new light duty vehicles. Context and appropriate comparisons are therefore important in comparing funding distributions.[42] A review of consumer survey and program application data completed by the Center for Sustainable Energy, as an example, showed the following: While 5.9% of rebate funds have gone to disadvantaged communities, that number increases to about 34% when normalized on comparable Light Duty Vehicle sales in California. The results of this analysis must thus come with the caveat that disparities in allocation are not to be blamed on program implementation but also on potential differences in demand for LDEV incentives around the state.

[42] Presentation: "Electric Vehicle Rebates in Disadvantaged Communities: Evaluating Progress with Appropriate Comparisons", 2016

Several variables were missing from the OLS model, as apparent with the low R-squared value. If the data had been available, controlling for consumer preferences of light duty passenger cars versus trucks, as well as new versus used vehicles, would have likely deepened the analysis assuming that these two variables vary geographically across the state. Indicators of environmentalism and other known factors that influence EV purchasing decisions would also have improved fit.

Finally, PEV and MileageSmart are only a part of Vermont's transportation decarbonization programming, and efficient vehicles are only a part of transportation efficiency. Go! Vermont, for example, offers carsharing and vanpooling services to help reduce single occupancy VMTs. According to Dan Currier, Public Transit Coordinator at VTrans, the program "is meant to fill the void where there's no public transit in Vermont," and offers incentives to help offset the cost for riders. Go! Vermont currently collects data on origin and destination, age, and gender of riders.[43] A more comprehensive study of Vermont transportation investments including public transit options and Go! Vermont is warranted to determine accessibility and affordability for disadvantaged communities.

Despite these caveats, this report provides an initial assessment of EV incentive program results and offers important insights on the types of metrics that could be analyzed if more granular data were collected. Further study should use Lorenz curves to approximate the fairness of rebate allocation across the state. The Lorenz curve should be used to find the horizontal and vertical equity coefficients (Gini and Suits respectively), a method that Guo and Kontou explain well in their 2021 analysis of the CVRP. Spatial analysis should also be further applied to understand neighboring and income effects of incentive uptake. Analyzing uptake over time, as the program is tweaked and EV technology evolves, could also be helpful. Greater attention paid to evaluating equity and justice in transportation programming will enable the state to better understand access issues within marginalized communities and to develop and implement more equitable state investments and policies in the future.

IV. Recommendations for Future EV Incentive Programs and Program Evaluations Vermont

As noted above, Vermont has already implemented a variety of policies and programs to increase EV adoption and to begin to enable access to EVs for those of all incomes. Informed by the qualitative and quantitative research conducted for this report, presented below are recommendations for Vermont to consider to further expand access to EVs for those with the highest transportation and environmental burden:

1. **Target incentives to those with the highest transportation and environmental burden using data beyond just income.**

Utilize transportation burden, the Vermont Environmental Disparity Index, and forthcoming assessment survey data to inform where to target incentive marketing, charging infrastructure planning, and dealership outreach. It is clear that EV incentives have potential to improve

[43] Dan Currier, Vermont Agency of Transportation, in conversation with the author, 19 July 2021.

transportation equity and justice where transportation burden and VT EDI are the highest, and that early investments in charging infrastructure facilitate uptake. Vermont should invest in marketing in these areas and focus on lifetime cost savings associated with ownership in order to improve uptake. Choosing certain high burden areas as focal points for a marketing, dealership outreach and charging infrastructure investment pilot program could be a promising way to better understand how to increase equity in EV adoption. Changing people's opinions and market decisions is difficult work that takes nuance and trust; a pilot would be a way to get started on a small scale and expand with lessons learned.

2. **Expand performance metrics**

Define performance metrics for assessing current conditions and track progress in the program design phase. Vermont can draw inspiration from the Mobility Equity Framework, which was developed by the Greenlining Institute for the purpose of increasing mobility equity in transportation planning and investments. The Institute reviewed various mobility indicators and reframed them through an equity lens to select indicators that would best represent progress towards impacts on low-income residents and communities of color.[44]

Table 1: Mobility Equity Framework Indicators

	Equity Indicators	Recommended Metrics
Goal #1: Increase Access to Mobility	1. Affordability	This metric will vary by transportation mode and location, and therefore should be set by the community; a recommended default is that households should spend no more than 20% of budgets on transportation costs[28]
	2. Accessibility	Transportation mode is physically accessible (available in neighborhood), accessible to disabled people, accessible to people with various cultures/languages, accessible without the need for banking or a smartphone
	3. Efficiency	Frequency of transit, travel times, time spent in traffic, optimal availability of parking, etc.
	4. Reliability	Consistency and variability of travel times, predictability of travel times
	5. Safety	Collision rate and severity;[39] personal safety issues (harassment, profiling, etc.)
Goal #2: Reduce Air Pollution	6. Clean Air and Positive Health Benefits	Quantities of air pollutants (PM, NOx) reduction,[40] level of physical activity, etc.
	7. Reduction in Greenhouse Gases	Quantities of greenhouse gas reduction[41]
	8. Reduction in Vehicle Miles Traveled	Compact development and greater clustering of destinations, VMT per capita

[44] The Greenlining Institute Mobility Equity Framework

Goal #3: Enhance Economic Opportunity		
9.	Connectivity to Places of Employment, Education, Services, & Recreation	Number of households by income within walking distance to schools and services. Number of households within 30-minute transit ride or 20-minute auto ride ofemployment center, etc[42] Number of transit transfers needed, time spent in transit.
10.	Fair Labor Practices	Fair wages, basic employment benefits and protections throughout construction, operation, and maintenance
11.	Transportation-Related Employment Opportunities	Direct and indirect employment throughout construction, operation, and maintenance
12.	Inclusive Local Business & Economic Activity	Local hire agreements, increased foot traffic to local businesses, new businesses created, increased property values, benefiting the local community without displacing residents, etc.

Given the initial findings of this analysis, key metrics for Vermont to track in future evaluation of the PEV Incentive Program would center around indicators 1, 2, and 7 shown in Table 1. The metrics might include a decrease in transportation burden spending, a decrease in percentage of the population without access to a vehicle, an increase in charging availability for communities with the highest transportation and environmental burdens. These metrics would help embed equity and justice concerns within the program more comprehensively than focusing simply on income levels.

3. Expand the VTrans/TRC survey

The plan to conduct a post-participation survey of the EV incentive program is an important opportunity to fill in several data gaps. The state should leverage questions to inform program design for the next round of funding. In California, data gathered from CVRP surveys have informed redesign many times since program inception, including in implementation and updates to income criteria and changes to eligible vehicles in the program. For example, after survey data from CVRP's first six years revealed that 88% incentives were captured by applicants with incomes greater than $75,000, the CVRP was amended to include an income cap that made higher income consumers who would likely have purchased an EV anyway ineligible.

Recommended questions or topics for the survey include the following:

- Demographics and Driver Characteristics
    - Age, gender, race/ethnicity
    - Housing characteristics
        - Rent/own
        - Type of Residence
        - Number and types of other vehicles in the household?
            - New/used/leased EV added to number or replaced another vehicle?
    - Mean commute

        - Is your typical workday commute location the same every workday or variable?
    - Frequency of trips longer than 100 miles
    - Change in weekly miles driven since EV?
- EVs and PHEVs purchase motivations
    - Mean repair cost when ICE vehicle was last repaired
    - Destination type prevented from reaching during repair?
    - Factors influencing purchase decision?
        - Primary and secondary motivation for purchase?
        - What factors gave hesitation?
    - What other vehicles did you consider?
    - Charging
        - How do you charge vehicle?
        - Presence of outlet within 25 feet of car?
            - 100 feet?
        - What time do you most frequently charge your EV at home?
            - Did you hire an electrician to hardwire EV charging equipment?
                - Are you aware of time-of-day rates offered by certain utilities and do you take advantage of them if available?
    - What topics are difficult to find information on? (i.e., comparing different EV models on features and cost, cost of home charging, EV vehicle safety, durability, warranties, etc.)
- Program Metrics
    - How satisfied were you with the application process?
    - Dealership experience
        - How knowledgeable was dealer representative in total cost of ownership, electricity rates to charge, home and away charging, government incentives and perks… etc.
    - How long did the process take between filling out the application and receiving the rebate?
    - How did you hear of incentive?
    - Are your peers/friends/fellow community members aware of the program?
    - How important were each of the following actors in making it possible to acquire new EV?
        - VT PEV incentive
        - Federal incentives
        - Utility Incentives
    - Would you have purchased or leased an EV if the incentive didn't exist?
    - If the incentive didn't exist, would you have chosen a less expensive version, different new EV, used EV, hybrid, gas/diesel vehicle, or no purchase? [45]

[45] Suggested questions were informed by CSE's administration of CVRP Consumer Survey and the MileageSmart Participant Survey.

Jamie Orose, Senior Evaluation Specialist at CSE, particularly emphasizes the counterfactual questions in survey design (e.g., Would you have purchased your EV regardless of the incentive?) in order to understand which demographics rely on the program the most. Demographic data like household size and income, race, gender, and ethnicity are also crucial to understanding who is participating over time and whether program adjustments lead to greater access. However, Orose also cautions against asking questions that might be considered intrusive and present an added barrier to adoption; "The balance is to think very carefully about is it imperative to know, or might be interesting but not crucial." Making surveys and certain questions within them voluntary is an important consideration.

4. **Supplement survey with mixed methods of evaluation**

Orose also recommends combining participant surveys with focus groups or interviews with priority populations. Combining feedback on the lived experiences of members of the most transportation-burdened communities with survey and income and location data of participants would best capture successes and shortcomings of programs. Working with community leaders within areas of low-uptake will also help gain buy-in from community members.

5. Improve data analysis and transparency

Once Vermont is able to collect demographic data on efficient transportation incentive programs, it is critical that the state make it publicly available. Karner et al. 2020 call for data accessibility in their recommendations for how to move from transportation equity to justice; "Transportation planners and scholars can benefit from critical assessments of these approaches."[46] This practice will hold the state accountable to its equity and justice principles by allowing outside actors to provide complementary assessments. California's principle of transparent data has facilitated the study of EV adoption on the state level that has paved the way for Vermont to improve their own policymaking. Figure 9 is taken from the CVRP website and shows the type of data collected and published.[47] Data from Vermont, a rural state with high relative early adoption rates, could similarly offer lessons to other similar states if publicly accessible.

6. Focus on affordability and availability

CARET is a software tool that takes a data driven approach to determining the optimal mix of EV incentives depending on the state goal. The algorithm in the tool is informed by Bass diffusion adoption curves from five years of data from 18 different jurisdictions globally aggregated to comprehensively understand barriers to purchasing. Clients input the amount, duration and type (used or new, scrap and replace, etc.) of potential incentives and they are

[46] Karner et al., 2020
[47] Center for Sustainable Energy, 2021

then able to explore program cost, the impact on EV market penetration, the charging infrastructure that will be needed, and the GHG reductions. The affordability calculator also identifies the models available scaled by household income to ensure affordability.[48] Karen Glitman commented on the tool's use: "From an equity lens, answering the question of whether the program design has made any EVs affordable is an important first step? The next question to answer is, is it available? If both of those are yes, then you can feel more confident that equity is achievable with that program design." Caret has helped inform the California program, a state that, while very different from Vermont, also has many rural and highly transportation-burdened areas as well. A further aspect of the tool particularly useful to ameliorating Vermont's rural equity disparities in EV adoption is its charging package. The tool takes desired attributes of a charging place and pairs them with utility and travel data to show where best to place the infrastructure.[49] State policymakers should ground truth any recommendations from the CARET tool with insights from key community in order to supplement a data-driven approach with "inclusive, transparent and innovative community engagement" as is called for in the Climate Council's Guiding Principles for a Just Transition.[50]

Figure 9: CVRP Equity Statistics published monthly by CSE

Rebates by Equity Group [2]

Timeframe: [1] Current Income Criteria (11/1/2016 – Present)

		Rebates	Funding	Percent of Funding
	All Equity Groups	**68,506**	**$189,693,869**	**33.5%**
Geography	**Disadvantaged Communities**	**22,219**	**$55,870,731**	**9.9%**
Geography	**Low-Income Communities**	**49,513**	**$121,762,274**	**21.5%**
Geography	*Disadvantaged Communities within Low-Income Communities*	*15,597*	*$39,829,022*	*7.0%*
Geography	*Low-Income Communities within 1/2 mile of a Disadvantaged Community* [2]	*9,869*	*$24,390,927*	*4.3%*
Rebate Type	**Increased Rebates for Low-/Moderate-Income Consumers** [1]	**20,623**	**$85,490,062**	**15.1%**

This chart summarizes the number of rebates, amount of funding, and the percent of funding by all equity groups, by geography, and by rebate type. Geography is broken down into two main categories: Disadvantaged Communities (DACs) and Low-Income Communities (LIC). LICs are further split into two subcategories based on distance to DACs.

V. Conclusion

[48] Center for Sustainable Energy, 2021
[49] Karen Glitman, Center for Sustainable Energy, in conversation with the author. 16 July 2021.
[50] "Guiding Principles for a Just Transition," 2021.

This paper adds three elements to the Vermont Transportation equity conversation: First, reasoning for why assessing equity and justice considerations within Vermont EV incentive programs are important. Second, a preliminary equity and justice assessment of PEV and MileageSmart Incentive Programs. Third, recommendations for improved programming evaluations and design. The analysis finds that while the majority of incentive funding is being directed towards low-income Vermonters, those recipients reside in areas with lower transportation burdens, higher population density, higher education rates, and more charging infrastructure available. Although limited by the geographic level of analysis and data availability, this study begins to demonstrate what can be understood about the current distribution of EV incentive funds in Vermont. This is timely work given the Vermont Climate Council's mandate to create equitable policy. Equitable incentive design informed by program participant data and the lived experiences of community members has the potential to increase EV adoption in higher transportation and environmentally burdened communities and ameliorate historically reinforced socioeconomic disparities.

VI. References

"The 2019 Vermont Transportation Energy Profile", November 2019. Vermont Agency of Transportation.

2020 Annual Energy Report, January 2020. State of Vermont Department of Public Service. https://publicservice.vermont.gov/content/2020-annual-energy-report

Act No. 59 (H.529). Transportation; motor vehicles; natural resources and energy; judiciary, 2019. https://legislature.vermont.gov/bill/status/2020/H.529

Bauer, Gordon, Chih-Wei Hsu, and Nic Lutsey. "When might lower-income drivers benefit from electric vehicles? Quantifying the economic equity implications of electric vehicle adoption." *The International Council on Clean Transportation.* Febuary 2021. https://theicct.org/publications/expanding-access-to-US-electric-mobility

Butler, Mei. EAN Emissions Reductions Pathways Model, August 2021. https://www.eanvt.org/ean-emissions-reductions-pathways-model/

Canepa, Kathryn, Hardman, Scott J, Tal, Gil, 2019. "An early look at plug-in electric vehicle adoption in disadvantaged communities in California." Transport Pol. 78, 19–30.

Center for Sustainable Energy, 2021. California Air Resources Board Clean Vehicle Rebate Project, Rebate Statistics. Data last updated April 14, 2021. Retrieved July 21, 2020 from cleanvehiclerebate.org/rebate-statistics.

Creger, Hana, Joel Espino, and Alvaro S. Sanchez, March 2018. "Mobility Equity Framework; How to Make Transportation Work for People." The Greenlining Institute.

Dan Currier, Vermont Agency of Transportation, in conversation with the author. 19 July 2021.

DeShazo, J.R., Sheldon, Tamara L., Carson, Richard T., 2017. "Designing policy incentives for cleaner technologies: lessons from California's plug-in electric vehicle rebate program." J. Environ. Econ. Manag. 84, 18–43.

Energy Action Network. Annual Progress Report, 2021. https://www.eanvt.org/tracking-progress/annual-progress-report/2021-annual-progress-report/

Greene, D. L., & Welch, J. G. (2017). "The Impact of Increased Fuel Economy for Light-Duty Vehicles on the Distribution of Income in the U. S .: A Retrospective and Prospective Analysis" (2:17; Issue March). Howard H. Baker Jr. Center for Public Policy. http://bakercenter.utk.edu/wp-content/ uploads/2017/03/WhitePaper2-2017.pdf

"Guiding Principles for a Just Transition." Vermont Climate Council, Just Transitions Subcommittee. June 2021 Draft.

Guo, Shuocheng, and Eleftheria Kontou. "Disparities and Equity Issues in Electric Vehicles Rebate Allocation." *Energy Policy*, vol. 154, 2021, p. 112291., doi:10.1016/j.enpol.2021.112291.

H.688, "Vermont Global Warming Solutions Act of 2020." https://legislature.vermont.gov/bill/status/2020/H.688

Hardman, Scott, Alan Jenn, Gil Tal, John Axsen, George Beardc, Nicolo Dainad, Erik Figenbaume, Niklas Jakobssonf, Patrick Jochemg, Neale Kinnearc, Patrick Plötzh, Jose Pontesi, Nazir Refaj, Frances Spreif, Tom Turrentinea, and Bert Witkampk. 2018. "A review of consumer preferences of and interactions with electric vehicle charging infrastructure." Transport. Res. Part D 62 (2018) 508–523

Howard, Bryan, Shruti Vaidyanathan, charlotte Coh, Nick Henner, and Ben Jennings. The State Transportation Electrification Scorecard, Febuary 2021. https://www.aceee.org/electric-vehicle-scorecard

Jamie Orose, Center for Sustainable Energy, in conversation with the author. 2 August 2021.

Jenn, Alan, Springel, Katalin, Gopal, Anand R., 2018. "Effectiveness of electric vehicle incentives in the United States." Energy Pol. 119, 349–356.

Johnson, Clair, Williams, Brett, 2017. "Characterizing plug-in hybrid electric vehicle consumers most influenced by California's electric vehicle rebate." Transport. Res. Rec. 2628 (1), 23–31.

Karen Glitman, Center for Sustainable Energy, in conversation with the author. 16 July 2021.

Karner, Alex, et al. "From Transportation Equity to Transportation Justice: Within, Through, and Beyond the State." *Journal of Planning Literature*, vol. 35, no. 4, 2020, pp. 440–459., doi:10.1177/0885412220927691.

Kerman, K. T. (2019). *Reducing Maintenance Costs With Electric Vehicles* (No. 255; NYC Fleet Newsletter, p. 2). Retrieved from NYC Citywide Administrative Services https://www1.nyc. gov/assets/dcas/downloads/pdf/fleet/NYC-Fleet-Newsletter-255-March-8-2019-Reducing- Maintenance-Costs-With-Electric-Vehicles.pdf

Langbroek, Joram HM., Franklin, Joel P., O Susilo, Yusak, 2016. "The effect of policy incentives on electric vehicle adoption." Energy Pol. 94, 94–103.

Lee, Jae Hyun, Hardman, Scott J, Tal, Gil, 2019. “Who is buying electric vehicles in California? Characterizing early adopter heterogeneity and forecasting market diffusion.” Energy Research & Social Science 55, 218–226.

Lutsey, N., & Nicholas, M. (2019). “Update on electric vehicle costs in the United States through 2030.” International Council on Clean Transportation. https://doi.org/10.13140/RG.2.2.25390.56646

Münzel, Christiane, Patrick Plo ̈tz, Frances Sprei, and Till Gnann, 2019. “How large is the effect of financial incentives on electric vehicle sales? A Global Review and European Analysis.” Energy Econ. 84, 104493.

Narassimhan, Easwaran, Johnson, Caley, 2018. “The Role of Demand-side Incentives and Charging Infrastructure on Plug-in Electric Vehicle Adoption: Analysis of US States.” Environ. Res. Lett. 13 (7), 074032.

Panikkar, Bindu. “Characterizing Environmental Justice Issues in Vermont,” May 2021. https://aoa.vermont.gov/sites/aoa/files/Boards/VCC/VT%20Climate%20coalition%20-%20Characterizing%20Environmental%20Justice%20Issues%20in%20Vermont%205-24-21.pdf

“Powering data-driven policy decisions to transform the EV market.” Center for Sustainable Energy, 2021. https://energycenter.org/software/caret

Propfe, Bernd, Martin Redelbach, Danilo J. Santini, and Horst Friedrich. 2012. "Cost analysis of Plug-in Hybrid Electric Vehicles including Maintenance & Repair Costs and Resale Values" *World Electric Vehicle Journal* 5, no. 4: 886-895. https://doi.org/10.3390/wevj5040886

Roberts, Dave. “Transportation Electrification in the State,” Lecture, August 2019. https://www.eanvt.org/featured-news/transportation-electrification-in-vermont/

Roberts, Dave. Memorandum to Dan Dutcher, VTRans. “State of Vermont Electric Vehicle Incentive Program Reporting,” December 2020.

Rowangould, Gregory. “Policy Insights from Electric Vehicle Markets in the Northeast and California.” Lecture, Febuary 2021. https://ncst.ucdavis.edu/events/capitol-hill-briefing-policy-insights-electric-vehicle-markets-northeast-and-california

Rubin D, St-Louis E. “Evaluating the Economic and Social Implications of Participation in Clean Vehicle Rebate Programs: Who’s In, Who’s Out?” Transportation Research Record. 2016;2598(1):67-74. doi:10.3141/2598-08

Samantha Hunt, Capstone, in conversation with the author. 12 July 2021.

Searle, S., Pavlenko, N., & Lutsey, N. September 2016. “Leading Edge of Electric Vehicle Market Development in the United States: An Analysis of California Cities.” International Council on Clean Transportation; www.theicct.org/ev-markets-calif-cities-sept2016.

Slowik, Peter and Michael Nicholas. "Expanding access to electric mobility in the United States." *The International Council on Clean Transportation.* December 2017. https://theicct.org/publications/expanding-access-to-US-electric-mobility

Supplemental Electric Vehicle Report Submitte21d Pursuant to Section 35 of Act 59 of the 2019-2020 Vermont Legislative Session, 2019. State of Vermont Department of Public Service. https://puc.vermont.gov/sites/psbnew/files/doc_library/EV-Supplemental-Report.pdf

Tal, Gil, and Michael Nicholas. "Exploring the Impact of the Federal Tax Credit on the Plug-In Vehicle Market." Transportation Research Record 2572, no. 1 (January 2016): 95–102. https://doi.org/10.3141/2572-11.

The Vermont Transportation Energy Profile, November 2019. https://vtrans.vermont.gov/sites/aot/files/planning/documents/planning/The%20Vermont%20Transportation%20Energy%20Profile_2019_Final.pdf

Vermont Environmental Disparity Index. https://www.arcgis.com/apps/webappviewer/index.html?id=68a9290bde0c42529460e1b8deee8368

Vermont Greenhouse Gas Emissions Inventory and Forecast: 1990 – 2017, May 2021. Vermont Agency of Natural Resources Air Quality and Climate Division. https://dec.vermont.gov/sites/dec/files/aqc/climate-change/documents/_Vermont_Greenhouse_Gas_Emissions_Inventory_Update_1990-2017_Final.pdf

VII. Appendix: Linear Regression Results

Table 1: OLS Regression Showing Effects of Various Factors on EV Incentive Usage Per Census Tract

	PEV Incentive			MileageSmart Incentive		
Coeffcient	*Estimates*	*Conf. Int (90%)*	*P-Value*	*Estimates*	*Conf. Int (90%)*	*P-Value*
Intercept	-1.00	-1.98 – -0.03	0.091	0.40	-0.28 – 1.08	0.332
Publicly Available Charging Stations Per Capita	0.24	0.05 – 0.42	0.037			
Rural	-0.34	-0.94 – 0.26	0.353	-0.02	-0.18 – 0.15	0.880
Percent Higher Education	2.70	1.52 – 3.88	<0.001	0.77	0.37 – 1.18	0.002
Median Age:	0.03	0.01 – 0.04	0.035	0.01	-0.00 – 0.02	0.137
Average Estimated Vehicle Miles Traveled	-0.01	-0.03 – 0.02	0.637	-0.00	-0.01 – 0.00	0.543
Median Income	0.00	0.00 – 0.00	0.063	-0.00	-0.00 – -0.00	0.020
Percent of Households Renting				-0.73	-1.31 – -0.15	0.039
Observations	183			66		
R^2 / R^2 adjusted	0.321 / 0.297			0.305 / 0.234		

Figure 1: Coefficient Plot