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APPENDIX A. VERMONT ELECTRICITY EMISSIONS INTENSITY DATA

The method used to estimate GHG emissions per unit of energy consumed follows the Vermont Public Utility Commission's method used to create the Vermont statewide GHG inventory, as described in conversations with the Vermont Public Service Department (A. Jacobs, personal communication, October 17, 2024). This method accounts for Renewable Energy Credits trading, the emissions factor of the New England grid, and distribution losses.

Each utility has a share of physical MWh delivered that is considered to have zero emissions because it is attributed to Renewable Energy Credits (RECs). The remaining percentage of MWh delivered is sourced from the New England Residual Mix. These percentages for 2023 were provided through files and discussion with the Vermont Service Department (A. Jacobs, personal communication, October 17, 2024).

The companies' emissions (in pounds of carbon dioxide per MWh) depend on the contents of the New England Residual Mix for the year. The most recently available data for the New England grid at the time of this estimation was from 2023. The total CO_2e emissions per MWh of New England Residual Mix is provided quarterly by NEPOOL GIS. Seasonal emissions were aggregated to an annual rate, yielding an emissions rate of 880.71 lbs CO_2 per MWh in the New England Residual mix in 2023, estimated from NEPOOL GIS (*NEPOOL Generation Information System: Residual Mix Report, 2023 Q1 to Q4*, 2025).

To determine emissions per MWh delivered by a utility company, the emissions per MWh of Residual Mix in 2023 was multiplied by the utility company's share of energy that is sourced from the Residual Mix, as shown in Table 1.

Table 1 Electric utility emissions intensity assumptions

Utility	Share of energy from NE residual mix in 2023	2023 emissions intensity (lbs CO2 per MWh of energy delivered)
Burlington Electric Department	0.00	0
Green Mountain Power	0.06	52.84
Village of Hyde Park Electric Department	0.33	290.63
Stowe Electric Department	0.20	176.14
Vermont Electric Co-op	0.25	220.18
Vermont Public Power Supply Authority	0.41	361.09
Washington Electric Co-op	0.06	52.84
Vermont overall	**0.10**	**88.07**

APPENDIX B. VERMONT FLEET TRENDS OVER TIME

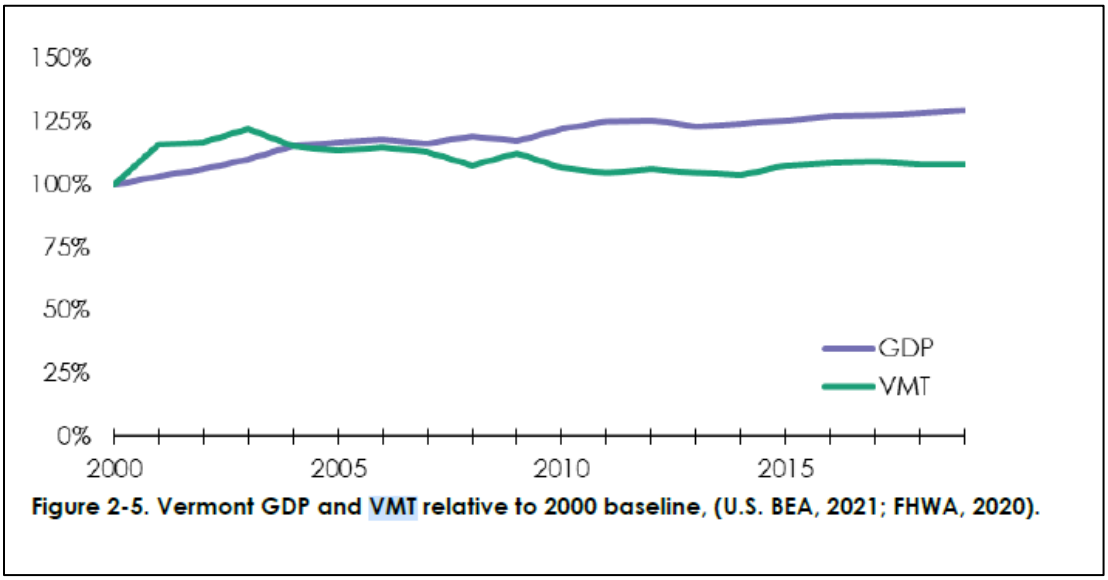

Figure 2-5. Vermont GDP and VMT relative to 2000 baseline, (U.S. BEA, 2021; FHWA, 2020).

Figure 1 Trend in Vermont Vehicle Miles Traveled from 2000 to 2019 (2021 report for Vermont Transportation Energy Profile)

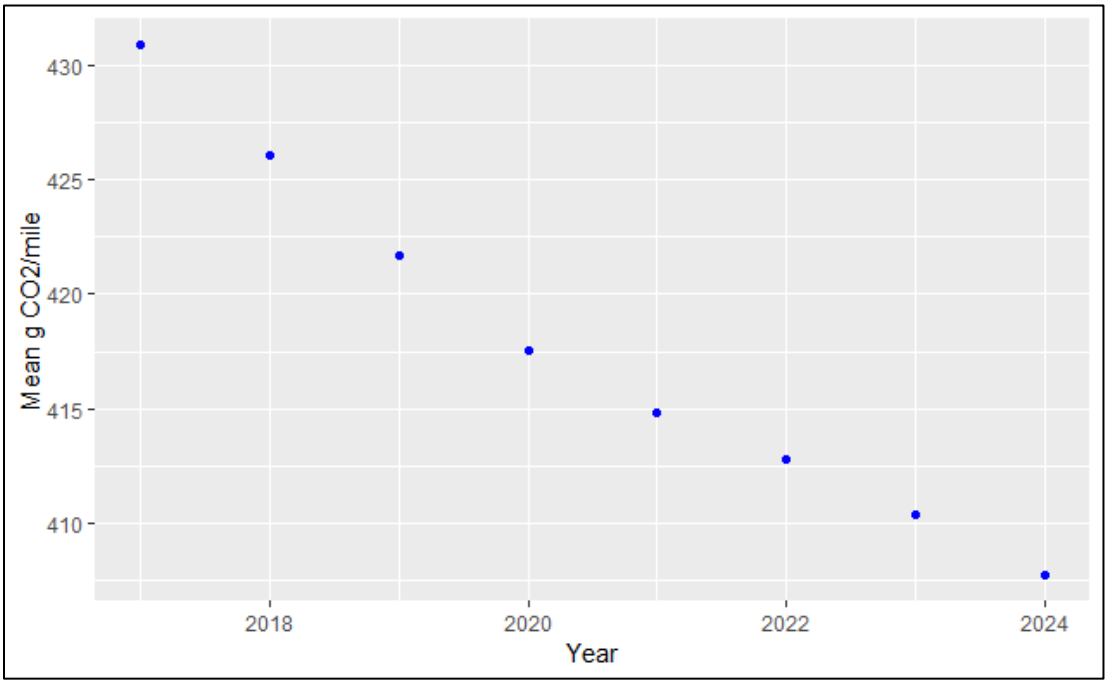

Figure 2 Average emissions intensity of passenger internal combustion vehicles in Vermont. The points trend downward at a rate of 0.79% per year.

APPENDIX C. SAMPLE EVALUATION

To characterize potential bias the "Households" table, we compared the characteristics of incentive households that were included in that sample to incentivized households in the "Incentives" and "Vehicle" tables.

Table 2 New PEV program: Attributes of samples in incentive, vehicle, and household tables

Incentive Level	**Enhanced**			**Standard**		
	Incentive	**Vehicle**	**Household**	**Incentive**	**Vehicle**	**Household**
n	2,496	1,430	292	2,106	1,425	404
Incentive Attributes						
Version 1 (before July 2023)	40%	54%	72%	55%	65%	84%
Vehicle Attributes						
Fuel Type						
BEV	77%	75%	68%	70%	70%	66%
PHEV	23%	25%	32%	30%	30%	34%
New	100%	100%	100%	100%	100%	100%
Purchased (vs leased)	42%	49%	60%	59%	64%	72%
Additional vehicle acquisition (vs replacement)	NA	57%	58%	NA	57%	50%
Recipient Attributes						
Low Income	100%	100%	100%	0%	0%	0%
Location Attributes						
Housing Type						
Multi-family	NA	18%	14%	NA	13%	13%
Single Family	NA	68%	68%	NA	76%	77%
Other	NA	3%	3%	NA	2%	1%
NA	NA	12%	15%	NA	9%	8%
Urban / Rural						
Urban	NA	35%	34%	NA	34%	36%
Rural	NA	51%	51%	NA	55%	56%
NA	NA	14%	15%	NA	11%	8%
Household Travel Attributes Mean (st dev)						
Vehicle count before incentive	NA	1.8 (1.3)	1.8 (0.9)	NA	1.9 (1.1)	1.9 (0.8)
Emissions intensity before incentive (kg CO_2 / mile)	NA	0.28 (0.16)	0.32 (0.12)	NA	0.28 (0.15)	0.31 (0.11)
Annual household VMT Before Incentive	NA	NA	17,800 (10,500)	NA	NA	21,100 (12,800)
Annual emissions before incentive (kg CO_2)	NA	NA	5,800 (4,100)	NA	NA	6,600 (4,600)

Table 3 MileageSmart program: Attributes of samples in incentive, vehicle, and household tablse

Incentive Level	**Standard**		
	Incentive	**Vehicle**	**Household**
n	1,277	946	157
Vehicle Attributes			
Fuel Type			
BEV	35%	32%	29%
PHEV	22%	21%	21%
HEV	43%	47%	50%
New	0%	0%	0%
Purchased (vs leased)	100%	100%	100%
Additional vehicle acquisition (vs replacement)	NA	63%	56%
Recipient Attributes			
Low Income	100%	100%	100%
Location Attributes			
Housing Type			
Multi-family	NA	24%	26%
Single Family	NA	59%	61%
Other	NA	5%	5%
NA	NA	12%	8%
Urban / Rural			
Urban	NA	35%	39%
Rural	NA	51%	52%
NA	NA	14%	8%
Household Travel Attributes Mean (st dev)			
Vehicle count before incentive	NA	1.6 (1.3)	1.6 (0.8)
Emissions intensity before incentive (kg CO_2 / mile)	NA	0.28 (0.16)	0.32 (0.11)
Annual household VMT Before Incentive	NA	NA	17,300 (11,400)
Annual emissions before incentive (kg CO_2)	NA	NA	5,800 (4,700)

Table 4 Replace Your Ride Program: Attributes of sample in incentive, vehicle, and household table

Incentive Level	**Enhanced**			**Standard**		
	Incentive	**Vehicle**	**Household**	**Incentive**	**Vehicle**	**Household**
n	334	180	15	94	42	6
Vehicle Attributes						
Fuel Type						
BEV	82%	79%	80%	79%	74%	83%
PHEV	18%	21%	20%	17%	19%	17%
HEV	0%	0%	0%	4%	7%	0%
New	59%	58%	80%	72%	67%	67%
Purchased (vs leased)	62%	69%	73%	65%	76%	100%
Additional vehicle acquisition (vs replacement)	NA	54%	67%	NA	52%	17%
Recipient Attributes						
Low Income	100%	100%	100%	33%	33%	67%
Location Attributes						
Housing Type						
Multi-family	NA	13%	7%	NA	26%	17%
Single Family	NA	67%	67%	NA	60%	67%
Other	NA	6%	7%	NA	0%	0%
NA	NA	14%	20%	NA	14%	17%
Urban / Rural						
Urban	NA	27%	27%	NA	45%	50%
Rural	NA	56%	53%	NA	40%	33%
NA	NA	17%	20%	NA	14%	17%
Household Travel Attributes						
Vehicle count before incentive	NA	2.0 (1.3)	1.8 (0.9)	NA	1.9 (1.1)	2.2 (0.4)
Emissions intensity before incentive (kg CO_2 / mile)	NA	0.32 (0.14)	0.35 (0.13)	NA	0.31 (0.13)	0.30 (0.07)
Annual household VMT Before Incentive	NA	NA	19,500 (12,200)	NA	NA	20,200 (9,300)
Annual emissions before incentive (kg CO_2)	NA	NA	7,000 (4,600)	NA	NA	5,700 (3,500)

Table 5 eBike program: Attributes of sample in incentive, vehicle, and household table

Incentive Level	**Enhanced**			**Standard**		
	Incentive	Vehicle	Household	Incentive	Vehicle	Household
n	463	286	92	124	84	39
Bike Attributes						
New	100%	100%	100%	100%	100%	100%
Purchased (vs leased)	100%	100%	100%	100%	100%	100%
Additional vehicle acquisition (vs replacement)	NA	82%	97%	NA	74%	79%
Recipient Attributes						
Low Income	100%	100%	100%	0%	0%	0%
Location Attributes						
Housing Type						
Multi-family	NA	21%	15%	NA	12%	10%
Single Family	NA	77%	83%	NA	83%	85%
Other	NA	1%	1%	NA	4%	5%
NA	NA	0%	1%	NA	1%	0%
Urban / Rural						
Urban	NA	47%	55%	NA	32%	26%
Rural	NA	45%	43%	NA	67%	74%
NA	NA	8%	1%	NA	1%	0%
Household Travel Attributes Mean (st dev)						
Vehicle count before incentive	NA	1.9 (1.2)	1.6 (0.6)	NA	2.2 (1.2)	2.2 (1.1)
Emissions intensity before incentive (kg CO_2 / mile)	NA	0.34 (0.12)	0.36 (0.10)	NA	0.35 (0.11)	0.35 (0.09)
Annual household VMT Before Incentive	NA	NA	15,900 (9,900)	NA	NA	21,700 (13,300)
Annual emissions before incentive (kg CO_2)	NA	NA	5,500 (4,100)	NA	NA	7,800 (5,300)

Table 6 Non-incentivized vehicle acquisitions: Attributes of sample in incentive, vehicle, and household table

	Vehicle	Household
n	984,836	151,599
Vehicle Attributes		
Fuel Type		
BEV	1%	1%
PHEV	1%	< 1%
HEV	3%	4%
ICE	95%	94%
New	19%	26%
Purchased (vs leased)	NA	NA
Additional vehicle acquisition (vs replacement)	73%	70%
Recipient Attributes		
Low Income	NA	NA
Location Attributes		
Housing Type		
Multi-family	16%	13%
Single Family	62%	70%
Other	4%	3%
NA	18%	14%
Urban / Rural		
Urban	30%	32%
Rural	52%	53%
NA	18%	15%
Household Attributes Mean (st dev)		
Vehicle count before incentive	1.5 (1.4)	1.7 (1.0)
Emissions intensity before incentive (kg CO_2 / mile)	0.30 (0.19)	0.36 (0.14)
Annual household VMT Before Incentive	NA	22,000 (14,900)
Annual emissions before incentive (kg CO_2)	NA	8,700 (6,200)

Table 7 No vehicle acquisitions: Attributes of sample in incentive, vehicle, and household table

	Vehicle	**Household**
n	4,538,592	873,153
Vehicle Attributes		
Fuel Type		
BEV	1%	1%
PHEV	1%	1%
HEV	3%	4%
ICE	95%	95%
New	NA	NA
Purchased (vs leased)	NA	NA
Additional vehicle acquisition (vs replacement)	NA	NA
Recipient Attributes		
Low Income	NA	NA
Location Attributes		
Housing Type		
Multi-family	12%	13%
Single Family	67%	68%
Other	3%	3%
NA	17%	16%
Urban / Rural		
Urban	30%	32%
Rural	53%	51%
NA	17%	16%
Household Attributes Mean (st dev)		
Vehicle count before incentive	2.4 (1.2)	2.0 (1.0)
Emissions intensity before incentive (kg CO_2 / mile)	0.40 (0.08)	0.39 (0.08)
Annual household VMT Before Incentive	NA	21,300 (15,100)
Annual emissions before incentive (kg CO_2)	NA	8,300 (6,300)

APPENDIX D. STATISTICAL MODELING

We trained a random forest on the household-level data in order to model change in GHG emissions from the year before the household receives an incentive to the year after. We used the random forest to predict household GHG change over one year for incentivized vehicles, including those that were not in the household sample.

D1. Variables

The outcome variable is change in GHG (kg CO_2), defined as total household emissions in the last year of the 3-year window minus the first year. Predictors are all are available in both Household and Vehicle datasets, such as year, household vehicle count by fuel type (BEV, PHEV, HEV, ICE), acquisition indicators (acquired BEV/HEV/PHEV/ICEV; acquired new/used vehicle), net vehicle change, household mean kg CO_2 per mile, and an indicator for each incentive program noting whether the household received one in the vehicle acquisition year (the second year of three-year period.) See Table 8 for descriptive statistics of model variables.

This analysis uses complete cases, meaning that no imputation was done to fill in missing values for any predictors and that observations with missing data were excluded from model training.

Table 8 Summary of random forest model variables

Variable	Type	Level / Statistic	N	Percent or value
Acquired BEV	Categorical	Did not acquire BEV	597,616	99.6%
		Acquired BEV	2,277	0.4%
Acquired PHEV	Categorical	Did not acquire PHEV	597,990	99.7%
		Acquired PHEV	1,902	0.3%
Acquired HEV	Categorical	Did not acquire HEV	592,936	98.8%
		Acquired HEV	6,960	1.2%
Acquired ICE	Categorical	Did not acquire ICE	458,369	76.4%
		Acquired ICE	141,572	23.6%
Acquired New Vehicle	Categorical	Did not acquire new vehicle	552,467	92.1%
		Acquired new vehicle	46,955	7.8%
Acquired Used Vehicle	Categorical	Did not acquire used vehicle	487,917	81.3%
		Acquired used vehicle	111,646	18.6%
BEV Count	Categorical	0	594,733	99.1%
		1	5,016	0.8%
		2+	196	0.04%
HEV Count	Categorical	0	568,436	94.7%
		1	29,443	4.9%
		2+	2,066	0.3%
Net Vehicle Change	Categorical	Net neutral	444,843	74.1%
		Net increase	96,979	16.2%
		Net decrease	58,218	9.7%
ICE Count	Categorical	0	25688	5%

		1	283604	46%
		2+	290686	47%
PHEV Count	Categorical	0	593,690	98.9%
		1	6,065	1.0%
		2+	190	0.03%
Incentive Level		Standard	661	0.1%
		Enhanced	416	0.7%
		No Incentive	598963	99.8%
New PEV incentive	Categorical	With New PEV incentive	785	0.13%
		No incentive	599255	99.87%
Mileage Smart		With MileageSmart incentive	169	0.03%
		No incentive	599871	99.97%
Replace your Ride incentive	Categorical	With RYR incentive	23	<0.001%
		No incentive	600017	99.99%
Ebike incentive		With Ebike incentive	123	0.2%
		No incentive	599917	99.98%
Analysis Year (year of incentive)	Categorical	2019	113705	18.9%
		2020	118451	19.7%
		2021	119538	19.9%
		2022	117223	19.5%
		2023	105250	17.5%
		2024	25873	4.3%
Household mean kg CO_2 per mile	Numeric	Mean (SD)	544753	0.38 (0.092)
Household absolute change kg CO_2 (dependent variable)	Numeric	Mean (SD)	536,428	-573 (5962)

D2. Data transformations and Sample weighting

Even though our model does not require normal data, we checked for normality for robustness and model efficiency. Two variables in the model exhibited skewed distributions: mean household emissions per mile (a predictor) and change in GHG (our outcome variable). To normalize, we applied the Yeo–Johnson transformation to both on the training data. We used this transformation because it allows us to back-transform predictions to kg CO_2 for interpretability. Additionally, this normalization method handles zeroes and negative values which exist in our distribution of change in GHG.

Our sample had an extreme imbalance of "treated" cases (households that received an incentive) and "untreated" cases (households that did not receive an incentive). Non-incentive households constituted over 99% of the sample. To improve our understanding of the effect of incentives on household GHGs, we used overlap weighting (average treatment effect in the overlap population, or ATO). This method emphasizes households that are comparable on variables other than treatment. We assessed the balance using standard mean differences and effective sample size.

D3. Model training and predictions

We trained a random forest because it captures nonlinear relationships and interactions, and because it handles mixtures of numbers and categories with little preprocessing. To make sure the training is robust, we fit the model using five-fold cross-validation. This method repeatedly splits the data into five parts, trains on four, and tests on the remaining one, rotating through. Our primary tuning target was mean absolute error (MAE) because it is less sensitive to a few extreme values than root mean squared error (RMSE). We still reported RMSE and a weighted R^2, but MAE was the error metric we optimized for when developing the model.

All preprocessing steps applied during training, such as the Yeo–Johnson transformation, encoding of categorical predictors, and construction of treatment weights, were stored and re-used later to ensure consistent definitions between datasets. Once trained on household level data, the model was applied to vehicle level records. We used the same set of input fields (matching the household variables) to get a predicted change in household GHG emissions for each incentivized vehicle. Because we saved the transformation parameters and factor encodings from training, scoring the vehicle file used the exact same definitions. All vehicle predictions were back-transformed to kg CO_2 and stored with the vehicle's existing attributes.

D4. Model evaluation

We evaluated the model's predictive performance using MAE, RMSE, and weighted R-squared. We assessed how well the model predicts both overall and within key subgroups such as incentive program, incentive level, and fuel type. For each group we reported weighted and unweighted MAE, RMSE, and weighted R-squared.

To assess overall calibration, we compared predicted vs. observed changes in household GHG emissions (change in GHG) and visualized these relationships in hex plots. Figure 3 shows predictions for all households, while Figure 4 isolates incentive recipient households. The dashed line represents perfect agreement between predicted and observed ΔGHG (change in GHG emissions). Most observations cluster tightly around this line, indicating that the model captures the direction and magnitude of change for most households, though variance increases at higher emission changes for households that did not receive an incentive.

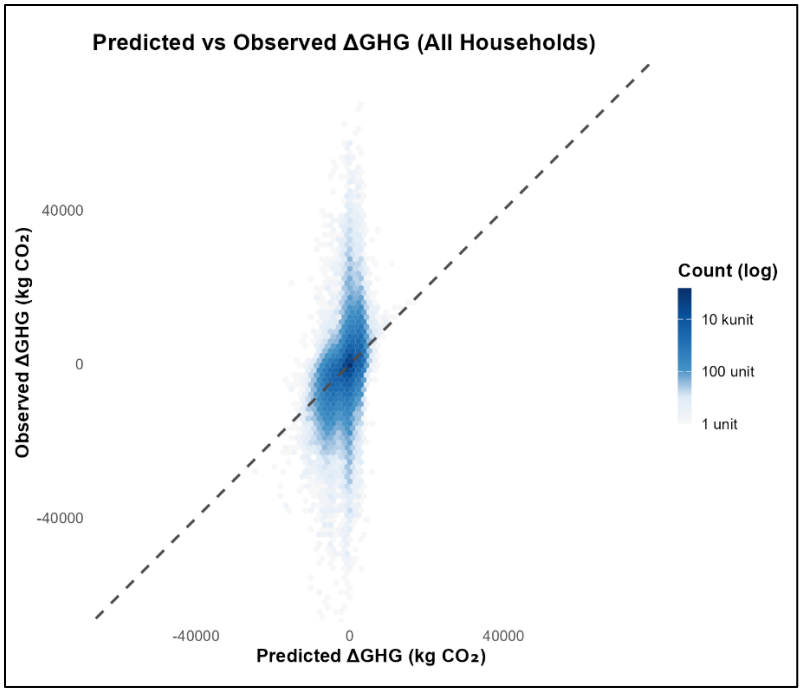

Figure 3 Predicted versus observed change in GHG for all households with complete records. Darker areas indicate a higher density of observations.

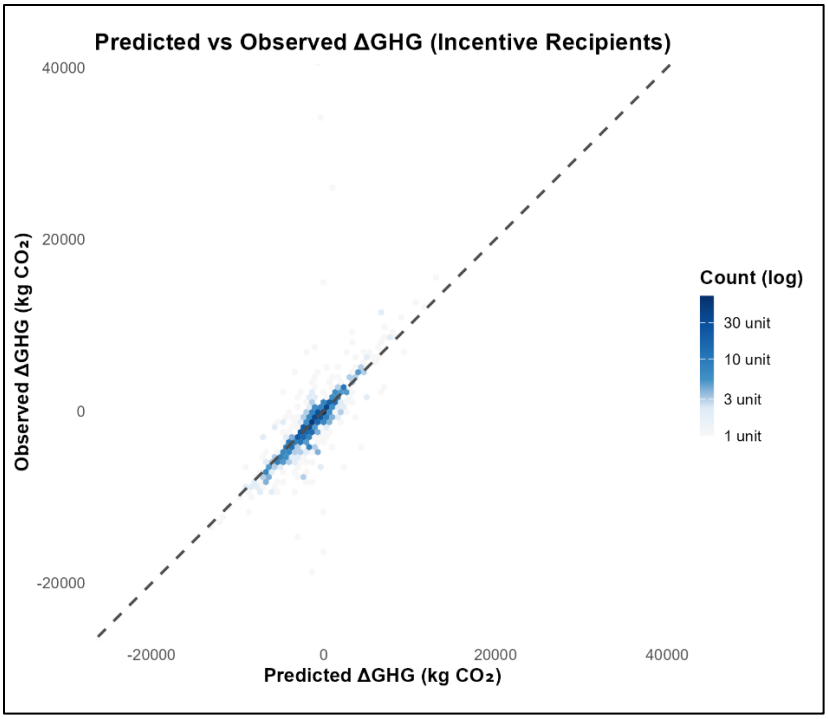

Figure 4 Predicted versus observed change in GHG for complete records for households receiving an incentive. Darker areas indicate a higher density of observations.

We also examined model residuals (observed minus predicted) as a function of fitted values for all modeled households and incentivized households in Figure 5 and Figure 6, respectively. The residual plot does not indicate strong heteroskedasticity or systematic bias in model performance, although there is mild underprediction for a few observations at the upper tail (large GHG reductions). The black smoothed line lies close to zero across most of the range of the majority of the data, confirming that the model performs well on average.

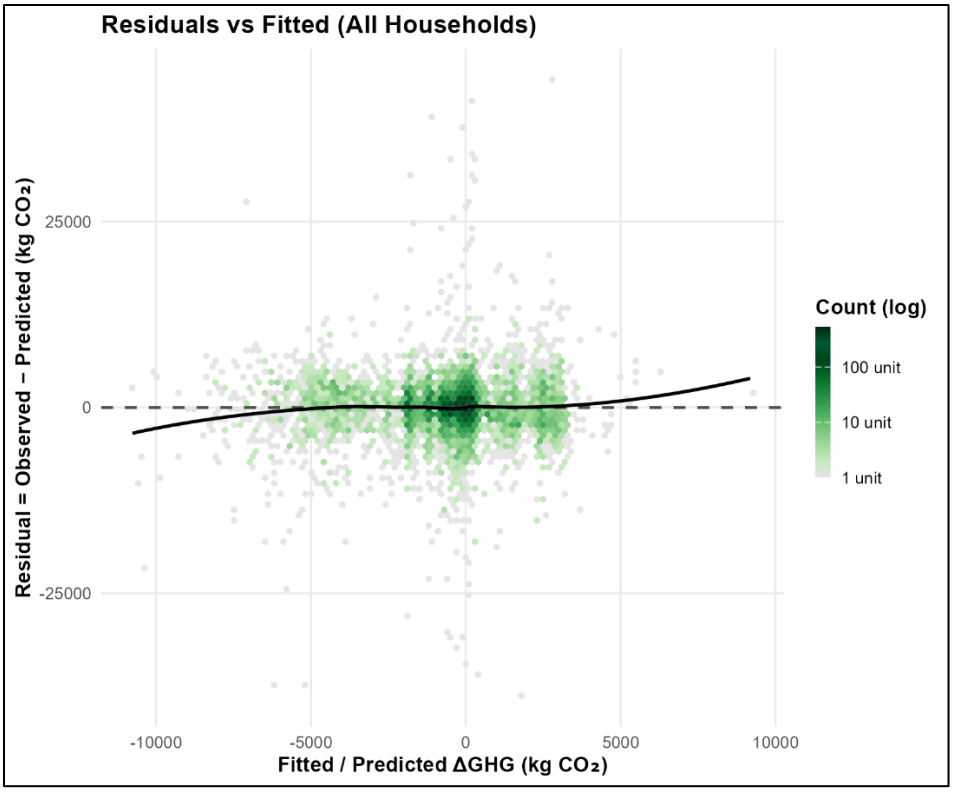

Figure 5 Model residuals for all households with complete records

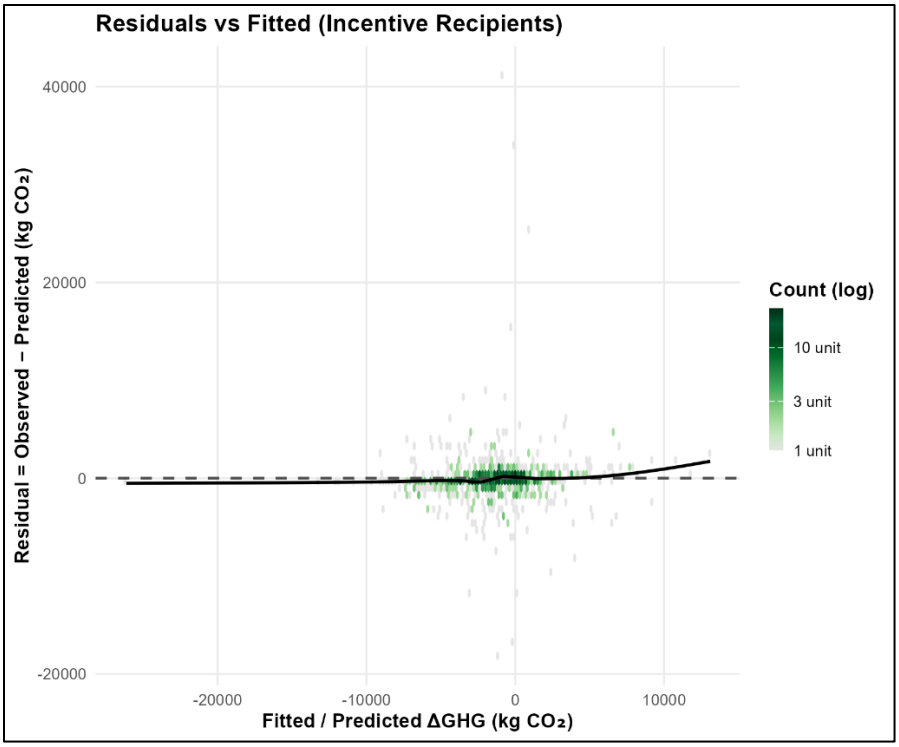

Figure 6 Model residuals for all incentivized households with complete records

Taken together, these diagnostics indicate that the model reproduces household emission change with balanced accuracy overall for household records with complete data. It neither systematically overestimates nor underestimates outcomes, and it successfully distinguishes households that reduced emissions from those whose emissions increased.

Finally, we evaluated model performance for subgroups that will be used to inform program design, including several categories that capture variations in incentive programs, levels, and vehicle types. As summarized in Table 9, predictive accuracy remained high across most programs. For the main incentive groups, mean absolute errors (MAE) typically ranged from 700 to 1,300 kg CO_2, indicating that the model reproduced household-level changes with reasonable precision. R squared values are also relatively high and show the predicting performance. To ensure that reported results are reasonable, we report the results of categories with a predicted mean within 10% of the observed mean in the main report.

Table 9: Evaluation of predicted 1-year GHG changes for incentive program variations.

Group	N	Weighted GHG change year-1 kg CO_2 Mean (st dev)		% difference	Predictions reported in report?	Mean Abs. Error	Root Mean Squared Error	R^2
		Predicted	Observed					
All households	536,403	-814.6 (2524)	-875.6 (3987.7)	7%	Yes	1401.3	2969.0	0.45
Any incentive (including eBikes)	961	-1274.6 (3006.5)	-1341.5 (4155.9)	5%	Yes	1085.1	2692.5	0.58
New PEV	694	-1553.6 (2845.4)	-1762.4 (3702.6)	12%	No	1089.3	2179.0	0.65
New PEV Enhanced	291	-1390.1 (2742.5)	-1478.3 (3224.3)	6%	Yes	884.0	1424.6	0.80
New PEV Standard	403	-1671.8 (2911.9)	-1967.8 (4000.5)	15%	No	1237.7	2591.0	0.58
New PEV Version 1	549	-1431.1 (2925.4)	-1661.2 (3794.2)	14%	No	1078.1	2161.8	0.68
New PEV Version 2	145	-2018.5 (2464.2)	-2146.4 (3304.4)	6%	Yes	1131.8	2242.9	0.54
New PEV BEV	455	-1740.1 (2746.8)	-1703.3 (3901.3)	-2%	Yes	1096.9	2398.5	0.62
New PEV PHEV	218	-1169.9 (3036.4)	-1950.4 (3265.4)	40%	No	1115.2	1695.6	0.73
New PEV + RYR	16	-2477 (3072)	-2456.1 (3408.2)	-1%	Yes	576.5	929.6	0.93
MileageSmart	155	-818.2 (3829.1)	-830.7 (4142.7)	1%	Yes	708.9	1379.1	0.89
MileageSmart BEV	40	-2394 (3432.3)	-2231.7 (3519)	-7%	Yes	479.8	960.5	0.93
MileageSmart PHEV	29	385.7 (2656.8)	-27.7 (2688.7)	1490%	No	647.9	1149.8	0.82
MileageSmart HEV	72	-404.3 (4240)	-350.4 (4830.2)	-15%	No	964.9	1741.6	0.87
MileageSmart + RYR	5	-981 (4359.8)	-1180.6 (4342.4)	17%	No	249.3	447.5	0.99
eBike	112	-180.7 (2263.7)	554.4 (5864.2)	133%	No	1579.8	5487.1	0.12
eBike Enhanced	79	-119 (2360.3)	977.2 (6741)	112%	No	1928.0	6432.4	0.09
eBike Standard	33	-328.5 (2005.6)	-458.3 (2542)	28%	No	745.5	1765.8	0.52
Incentivized BEV	495	-1793 (2814.2)	-1746.1 (3874.5)	-3%	Yes	1047.0	2315.6	0.64
Incentivized HEV	72	-404.3 (4240)	-350.4 (4830.2)	-15%	No	964.9	1741.6	0.87
Incentivized PHEV	247	-987 (3035.9)	-1724.3 (3262.3)	43%	No	1060.3	1640.9	0.75
Incentivized vehicle lease	230	-1760.9 (2639.2)	-1698 (3465.6)	-4%	Yes	1075.3	1969.7	0.68
Incentivized vehicle purchase	619	-1292.1 (3196)	-1552.7 (3921.6)	17%	No	999.1	2087.3	0.72
Incentivized vehicle new	694	-1553.6 (2845.4)	-1762.4 (3702.6)	12%	No	1089.3	2179.0	0.65
Incentivized vehicle used	155	-818.2 (3829.1)	-830.7 (4142.7)	1%	Yes	708.9	1379.1	0.89

Group	N	Weighted GHG change year-1 kg CO_2 Mean (st dev)		% difference	Predictions reported in report?	Mean Abs. Error	Root Mean Squared Error	R^2
		Predicted	Observed					
BEV without Incentive	1,224	-1522.4 (1977.9)	-1605.4 (3134.5)	5%	Used in free rider estimation	973.5	2170.4	0.52
PHEV without Incentive	1,130	-665.1 (2108.8)	-1378.8 (3259.2)	52%	Used in free rider estimation	1363.3	2469.1	0.43
HEV without incentive	5,030	-57.1 (2262.7)	-146.4 (4029)	61%	Used in free rider estimation	1710.1	3048.5	0.43
ICE without incentive	114,923	939.4 (2136.4)	915.1 (4993.1)	-3%	Used in free rider estimation	2789.8	4395.7	0.22
No vehicle acquisition	411,517	-668.5 (1523.9)	-724.4 (3299.6)	8%	Used in free rider estimation	1467.8	2887.6	0.23

D6. Variable importance

To understand which variable the forest used or prefers most, we used permutation importance. The method randomly shuffles one predictor at a time and sees how much the prediction error worsens. Larger increases show greater importance for predictive accuracy. A few variables, like the incentive program indicators, show near-zero importance. This does not mean incentives don't matter. It means that, for prediction, the forest often prefers the variables that explain GHG change most, such as Acquired BEV.

As shown in Figure 7, net vehicle change (whether a household increased, decreased, or maintained its vehicle count) dominated model importance. This makes sense because changes in vehicle fleet size are the strongest direct driver of changes in total emissions. Other highly influential predictors included whether the household acquired an internal combustion engine (ICE) vehicle, the number of ICE vehicles at beginning of the year, and the analysis year (year of incentive). These are highly correlated with the program flags, so the program indicator may add little additional predictive signal when these acquisition variables are present. Small sample sizes for some programs also make it harder for a shuffling test to register a clear importance, and correlated variables tend to share credit in permutation schemes. It is important to mention that permutation importance is about predictive contribution, not a causal effect.

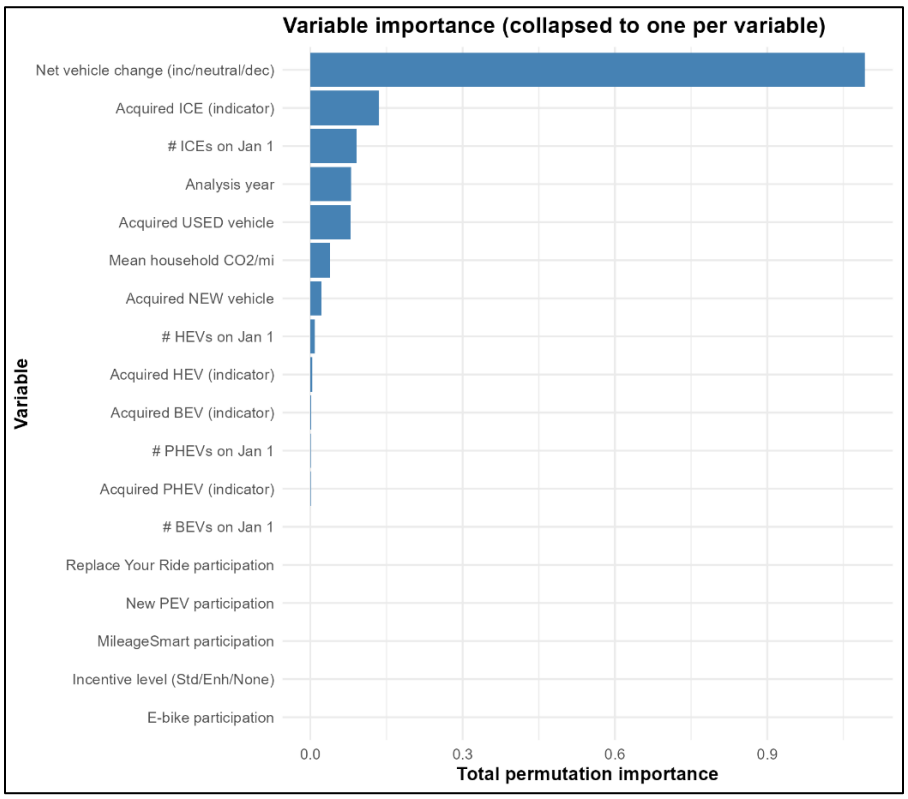

Figure 7 Variable importance of model predictors

D7. Sample bias correction

To evaluate sample bias correction from the machine learning model, we compare the average observed GHG emissions change in the smaller sample household table used to train the model to 1) the average predicted GHG emissions change in the household sample and 2) the average predicted GHG emissions change in the larger sample in the vehicle table. This comparison illustrates the correction yielded by the step of using machine learning to extrapolate the relationships observed in the smaller household sample to the larger vehicle sample.

As shown in Table 10, the predicted emissions changes across all groups are greater in the vehicle table compared to their respective observed changes in the household table. This suggests that for the reported groups, estimates based on the smaller sample of incentives in the household table produced smaller changes in emissions compared to the more complete sample in the vehicle table.

Table 10 Sample bias correction: observed versus predicted GHG change for 1 year

Program	Category	Emissions savings year after incentive in metric ton CO_2[1] Mean (st dev)		
		Observed (household table)	Predicted (household table)	Predicted (vehicle table)
New PEV	Enhanced	1.3 (3.4)	1.4 (2.7)	1.8 (2.6)
	Version 2	2.1 (3.3)	2.0 (2.5)	2.3 (2.1)
	BEV	1.7 (3.8)	1.7 (2.7)	2.0 (2.5)
New PEV + RYR	All	2.5 (3.5)	2.5 (3.2)	2.6 (2.6)
MileageSmart	All	0.8 (4.2)	0.8 (3.8)	1.1 (3.2)
	BEV	2.2 (3.5)	2.4 (3.4)	1.7 (2.9)
Vehicle programs (no eBike or Electrify Your Fleet)	BEV	1.7 (3.9)	1.8 (2.8)	2.0 (2.6)
	Leased	1.6 (3.6)	1.8 (2.6)	2.0 (2.6)
	Used	0.8 (4.2)	0.8 (3.8)	1.1 (3.2)
All programs (no Electrify Your Fleet)	All	1.3 (4.2)	1.3 (3.0)	1.6 (2.8)

[1] This table shows GHG emissions changes without free rider adjustments or lifetime emissions calculations.

APPENDIX E. SENSITIVITY ANALYSIS OF INCENTIVE BENEFITS AND COST EFFECTIVENESS

Tables 11 to 14 summarize a sensitivity analysis of the estimated GHG benefits of vehicle incentives using scenarios that vary in terms of three assumptions: the discount rate applied to GHG emissions benefits, the incentivized vehicle's lifetime, and the rate of free riders (incentive recipients who would have bought a comparable vehicle anyway). In each table the values in **bold** indicate GHG reduction benefits that are estimated to have a value greater than or equal to than the cost of an incentive.

Table 11 Incentive cost and estimated value of GHG benefits using the 1.5% near-term Ramsey discount rate

Program	Category	Cost of an incentive Mean (st dev) incentive amount in 2024 $	Value of an incentive's GHG benefits over vehicle lifetime Mean (st dev) in 2024 $			
			Short vehicle lifetime		Long vehicle lifetime	
			High free rider rate	Low free rider rate	High free rider rate	Low free rider rate
New PEV	Enhanced	$4,400 ($900)	$2,100 ($6,000)	$3,600 ($6,100)	$4,100 ($11,400)	**$6,800 ($11,600)**
	Version 2	$3,600 ($1,400)	$2,600 ($5,500)	**$4,200 ($5,400)**	**$5,100 ($10,600)**	**$8,000 ($10,300)**
	BEV	$3,800 ($1100)	$2,100 ($6,200)	**$4,000 ($6,300)**	**$4,100 ($11,700)**	**$7,600 ($12,000)**
New PEV + RYR	All	$8,700 ($2100)	$2,800 ($5,500)	$4,300 ($5,800)	$5,500 ($10,500)	$8,400 ($11,000)
MileageSmart	All	$4,700 ($1000)	$900 ($3,900)	$1,200 ($4,000)	$2,500 ($9,800)	$3,200 ($10,000)
	BEV	$4,900 ($800)	$1,600 ($3,400)	$2,300 ($3,700)	$4,000 ($8,300)	**$5,700 ($8,600)**
Vehicle programs (no eBike or Electrify Your Fleet)	BEV	$4,300 ($1,800)	$2,100 ($5,800)	$3,800 ($6,000)	$4,200 ($11,300)	**$7,400 ($11,600)**
	Leased	$4,000 ($1,800)	$2,100 ($6,200)	$3,700 ($6,300)	**$4,100 ($11,900)**	**$7,100 ($12,000)**
	Used	$5,100 ($1,700)	$900 ($3,800)	$1,100 ($4,000)	$2,400 ($9,600)	$3,100 ($9,900)
All programs (no Electrify Your Fleet)	All	$3,700 ($2,000)	$1,900 ($5,500)	$2,900 ($5,800)	**$3,700 ($10,900)**	**$5,800 ($11,300)**

Table 12 Incentive cost and estimated value of GHG benefits using the 2% near-term Ramsey discount rate

Program	Category	Cost of an incentive Mean (st dev) incentive amount in 2024 $	Value of incentive GHG benefits over vehicle lifetime Mean (st dev) in 2024 $			
			Short vehicle lifetime		Long vehicle lifetime	
			High free rider rate	Low free rider rate	High free rider rate	Low free rider rate
New PEV	Enhanced	$4,400 ($900)	$1,300 ($3,500)	$2,100 ($3,600)	$2,500 ($6,800)	$4,100 ($6,900)
	Version 2	$3,600 ($1,400)	$1,600 ($3,300)	$2,500 ($3,200)	$3,100 ($6,300)	**$4,800 ($6,200)**
	BEV	$3,800 ($1,100)	$1,300 ($3,600)	$2,300 ($3,700)	$2,500 ($7,000)	**$4,500 ($7,200)**
New PEV + RYR	All	$8,700 ($2,100)	$1,700 ($3,300)	$2,600 ($3,400)	$3,300 ($6,300)	$5,100 ($6,600)
MileageSmart	All	$4,700 ($1,000)	$500 ($2,300)	$700 ($2,300)	$1,500 ($5,800)	$1,900 ($6,000)
	BEV	$4,900 ($800)	$900 ($2,000)	$1,400 ($2,200)	$2,400 ($4,900)	$3,400 ($5,100)
Vehicle programs (no eBike or Electrify Your Fleet)	BEV	$4,300 ($1,800)	$1,300 ($3,400)	$2,200 ($3,600)	$2,500 ($6,800)	$4,200 ($7,200)
	Leased	$4,000 ($1,800)	$1,300 ($3,700)	$2,200 ($3,700)	$2,500 ($7,100)	**$4,400 ($6,900)**
	Used	$5,100 ($1,700)	$500 ($2,200)	$700 ($2,300)	$1,500 ($5,700)	$1,800 ($5,900)
All programs (no Electrify Your Fleet)	All	$3,700 ($2,000)	$1,100 ($3,300)	$1,700 ($3,400)	$2,200 ($6,500)	$3,500 ($6,800)

Table 13 Incentive cost and estimated value of GHG benefits using the 2.5% near-term Ramsey discount rate

Program	Category	Cost of incentive Mean (st dev) incentive amount - 2024 $	Value of lifetime GHG benefits Mean (st dev) in 2024 dollars			
			Short vehicle lifetime		Long vehicle lifetime	
			High free rider rate	Low free rider rate	High free rider rate	Low free rider rate
New PEV	Enhanced	$4,400 ($900)	$800 ($2,200)	$1,300 ($2,200)	$1,500 ($4,300)	$2,600 ($4,300)
	Version 2	$3,600 ($1,400)	$1,000 ($2,000)	$1,500 ($2,000)	$1,900 ($4,000)	$3,000 ($3,900)
	BEV	$3,800 ($1,100)	$800 ($2,300)	$1,500 ($2,300)	$1,600 ($4,400)	$2,900 ($4,500)
New PEV + RYR	All	$8,700 ($2,100)	$1,000 ($2,000)	$1,600 ($2,100)	$2,100 ($4,000)	$3,200 ($4,200)
MileageSmart	All	$4,700 ($1,000)	$300 ($1,400)	$400 ($1,400)	$900 ($3,600)	$1,200 ($3,700)
	BEV	$4,900 ($800)	$600 ($1,200)	$800 ($1,300)	$1,500 ($3,100)	$2,100 ($3,200)
Vehicle programs (no eBike or Electrify Your Fleet)	BEV	$4,300 ($1,800)	$800 ($2,100)	$1,400 ($2,200)	$1,600 ($4,200)	$2,800 ($4,300)
	Leased	$4,000 ($1,800)	$800 ($2,300)	$1,400 ($2,300)	$1,600 ($4,400)	$2,700 ($4,500)
	Used	$5,100 ($1,700)	$300 ($1,400)	$400 ($1,400)	$900 ($3,600)	$1,100 ($3,700)
All programs (no Electrify Your Fleet)	All	$3,700 ($2,000)	$700 ($2,000)	$1,100 ($2,100)	$1,400 ($4,100)	$2,200 ($4,200)

Table 14 Cost effectiveness of incentive programs

Program	Category	Cost per metric ton CO_2 averted (2024 dollars)			
		Short vehicle lifetime		Long vehicle lifetime	
		High free rider rate	Low free rider rate	High free rider rate	Low free rider rate
New PEV	Enhanced	$930	$510	$560	$300
	Version 2	$620	$340	$390	$210
	BEV	$790	$430	$430	$230
New PEV + RYR	All	$1,400	$740	$910	$490
MileageSmart	All	$2,300	$870	$1,800	$690
	BEV	$1,400	$560	$940	$390
Vehicle programs (no eBike or Electrify Your Fleet)	BEV	$900	$510	$480	$270
	Leased	$850	$460	$460	$270
	Used	$2,600	$2,000	$970	$770
All programs (no Electrify Your Fleet)	All	$890	$560	$470	$300

APPENDIX F. UNCORRECTED OBSERVATIONAL DATA

The following visualizations show observed data for vehicles and households that have complete data. Plots that visualize VMT or GHG emissions require vehicles to have an inspection record. Plots that visualize household changes in GHGs over a three-year time period require households to have at least one common VIN throughout the time period. **Because of data limitations, these samples are not corrected for bias and may not be representative of the entire vehicle or household population in Vermont.**

F.1 Uncorrected annual VMT of Vermont vehicles

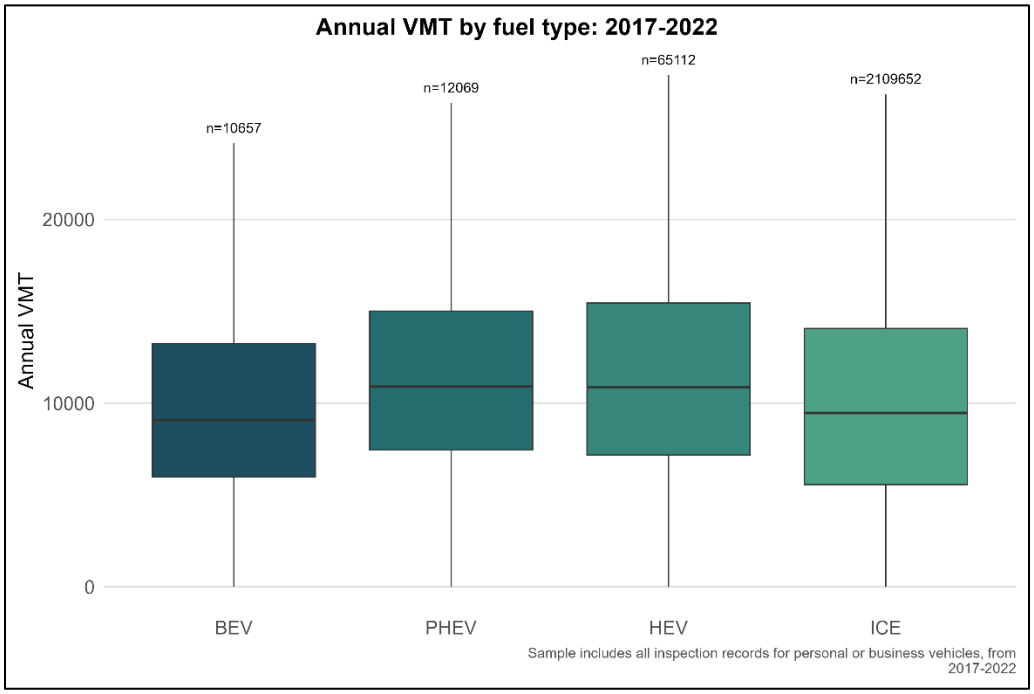

Figure 8 Annual VMT 2017 – 2022 by fuel type for households with complete data.

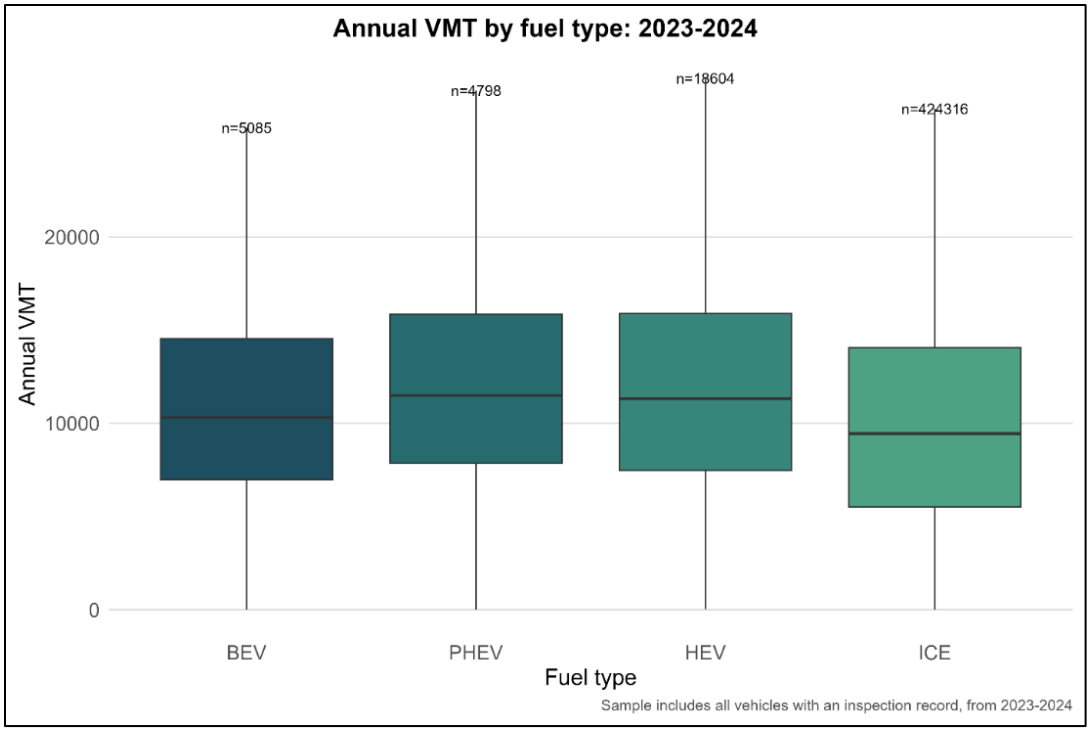

Figure 9 Annual VMT in 2023 – 2024 by fuel type for households with complete data.

F.2 Uncorrected household GHG change

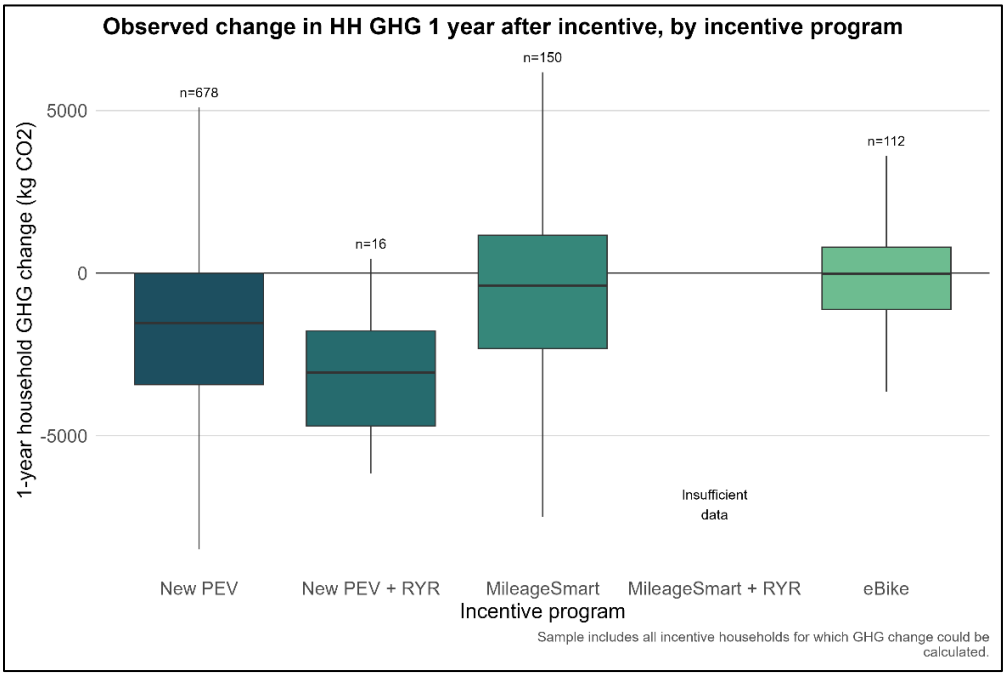

Figure 10: Observed 1-year change in GHG emissions by incentive program for households with complete data

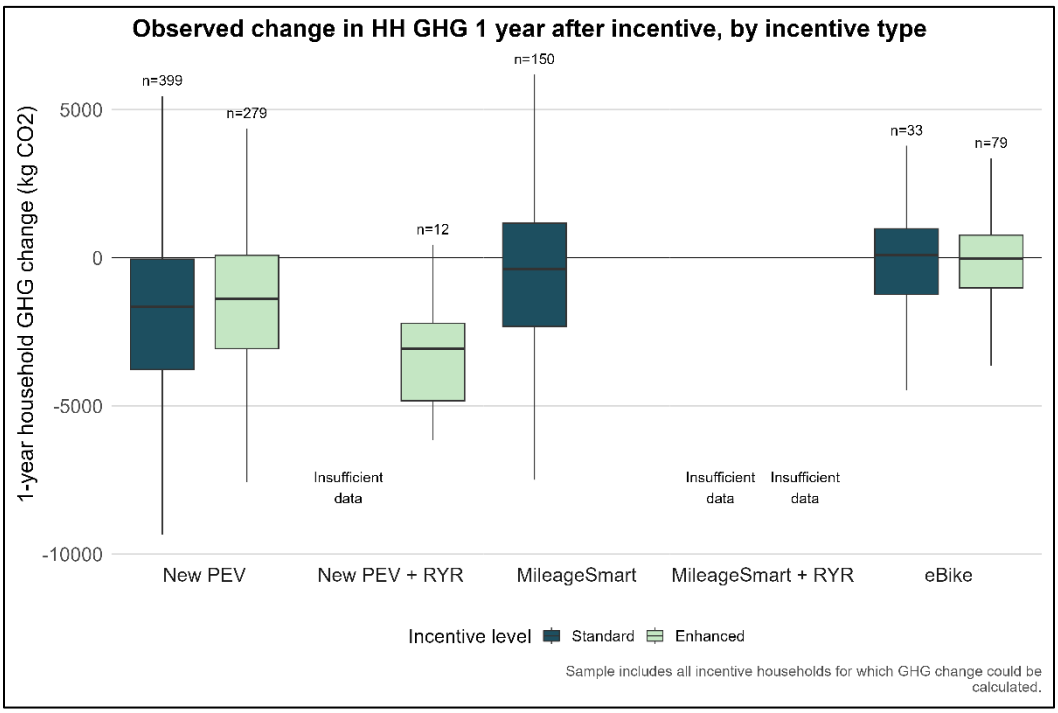

Figure 11 Observed 1-year change in GHG emissions by incentive program and level for households with complete data

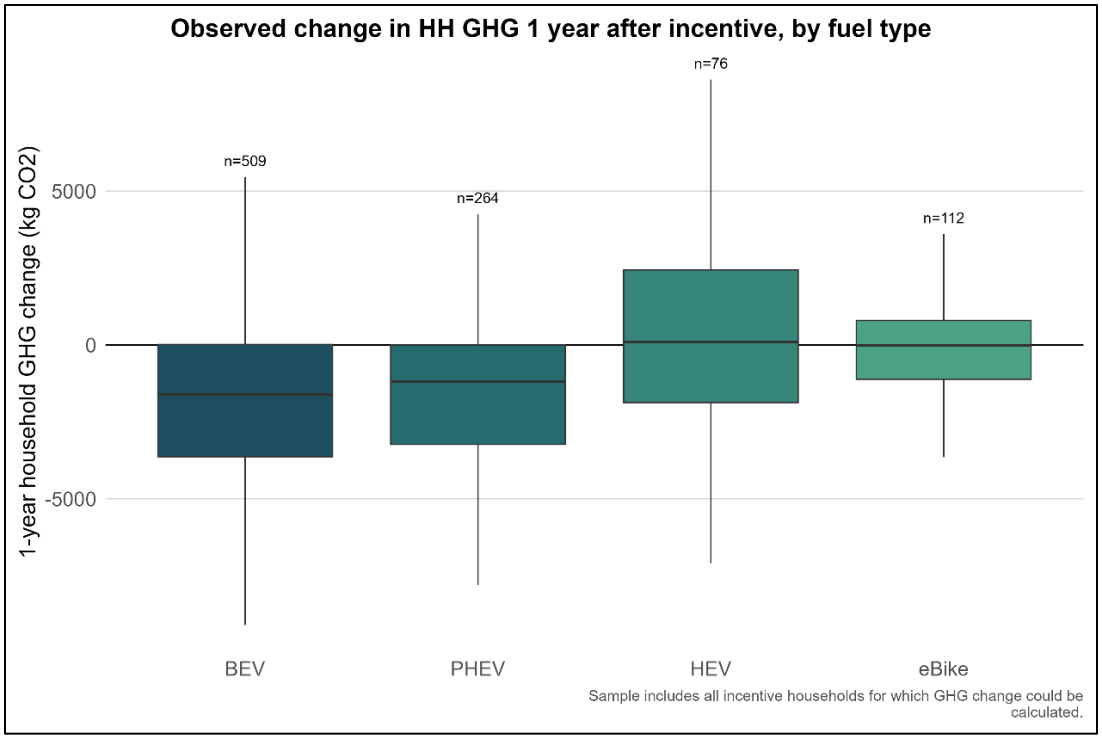

Figure 12 Observed 1-year change in GHG emissions by incentivized vehicle fuel type for households with complete data

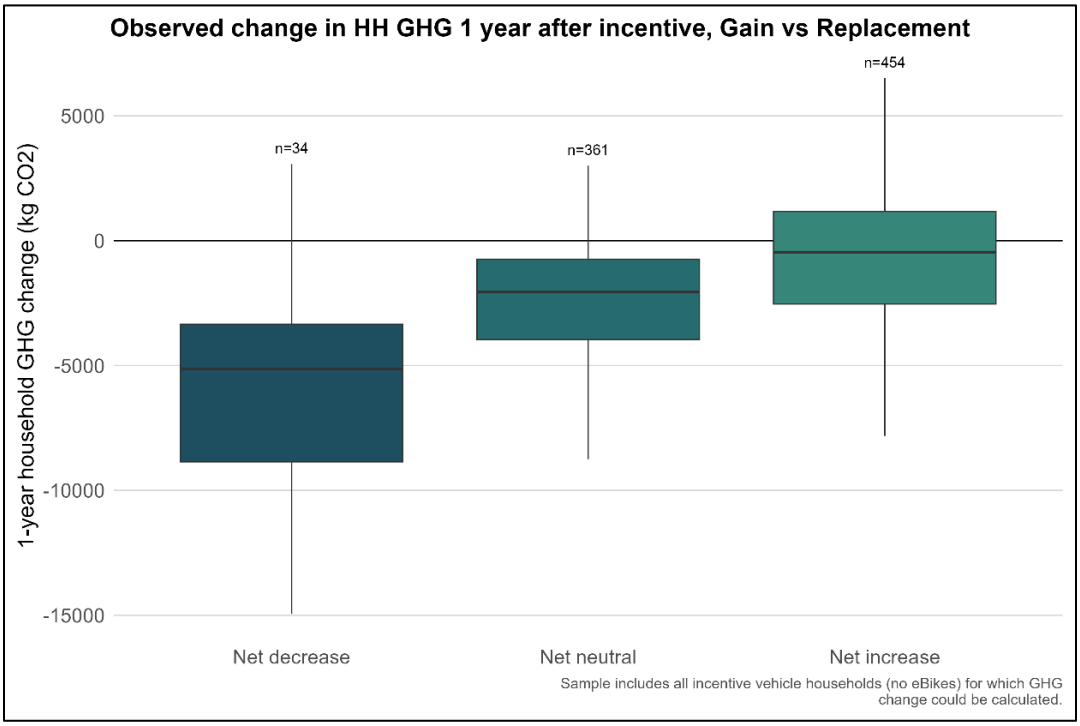

Figure 13 Observed 1-year change in GHG emissions by net change in household vehicles for households with complete data

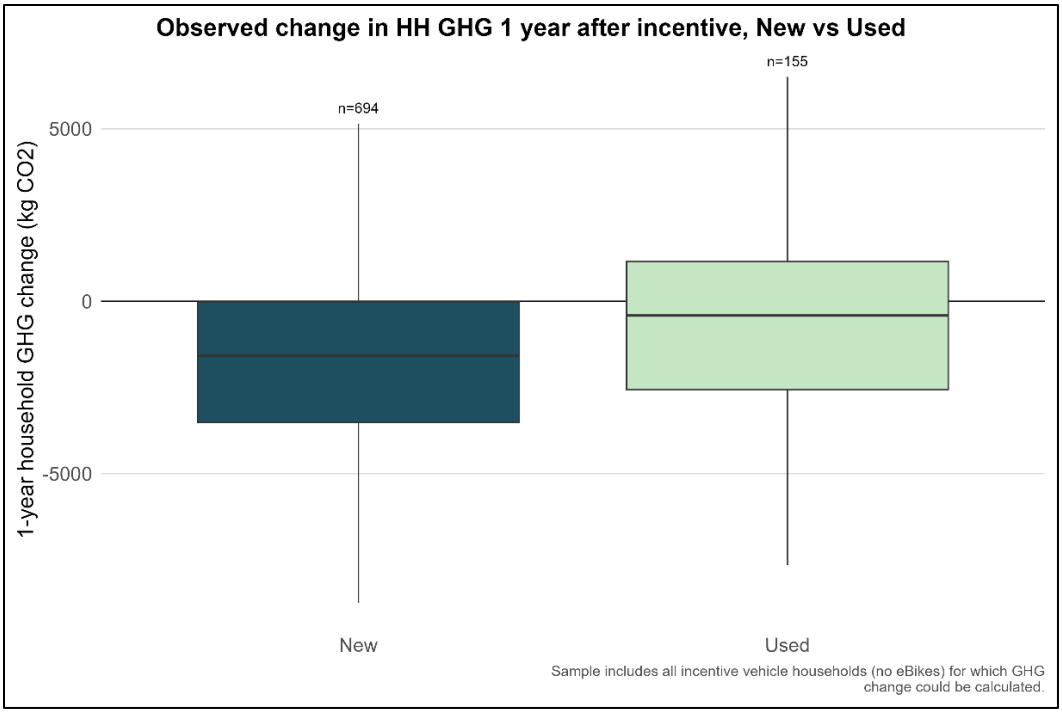

Figure 14 Observed 1-year change in GHG emissions for used and new vehicle acquisitions for households with complete data

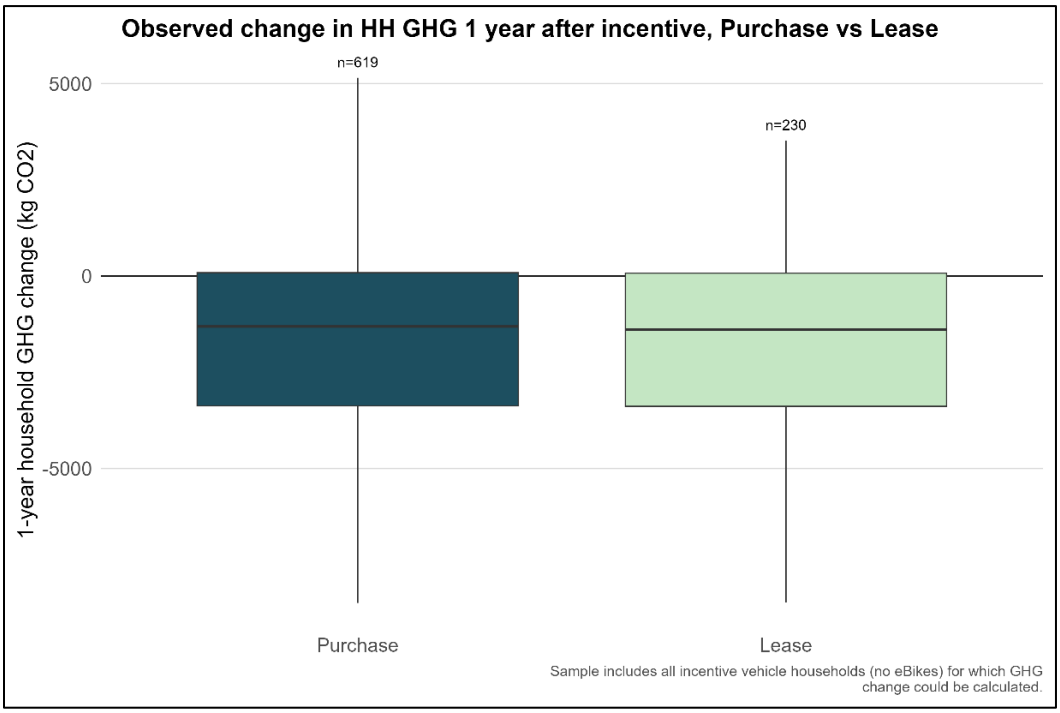

Figure 15: Observed 1-year change in GHG emissions for purchased and leased incentivized vehicles for households with complete data

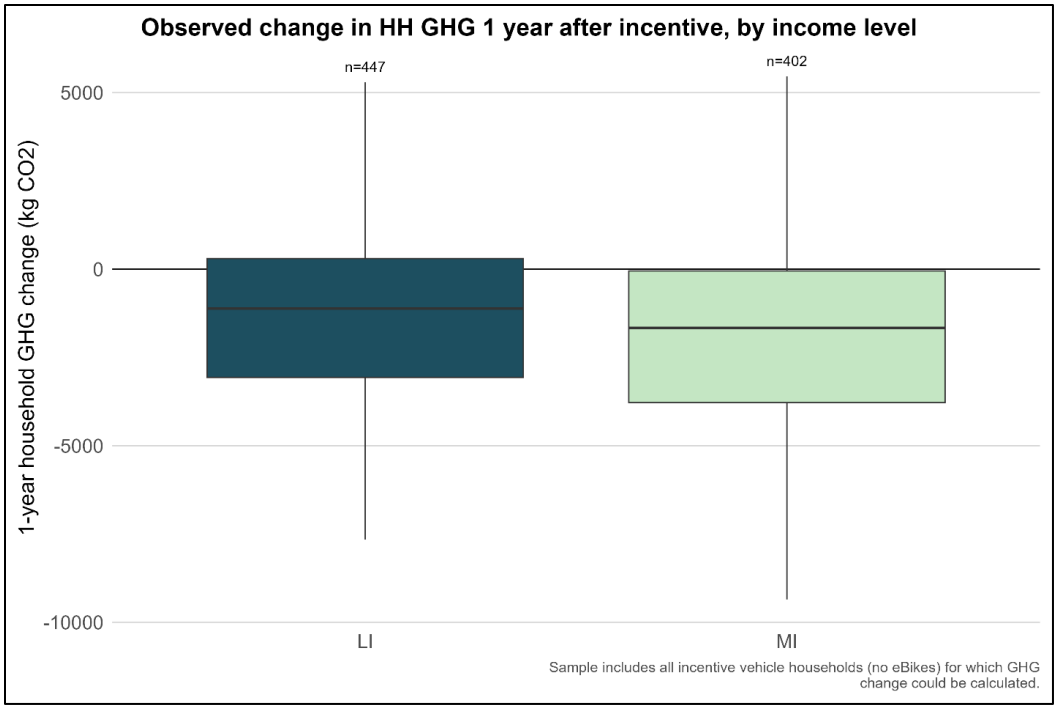

Figure 16: Observed 1-year change in GHG emissions for low income (LI) and middle income (MI) households for households with complete data

F.3 Predicted household emissions change in the year after incentive

The random forest model was used to predict GHG change for incentive households in the year after they received the incentive. These predictions are then adjusted using two free rider scenarios (described in Table 9 of the project report) to calculate an upper and lower estimate of the emissions changes that can be attributed to the incentive. The following plots show the distributions of predicted year-after-incentive household GHG change for the reported groups before adjusting for free riders (Figure 17), with the low GHG change free rider adjustment (Figure 18), and with the high GHG change free rider adjustment (Figure 19).

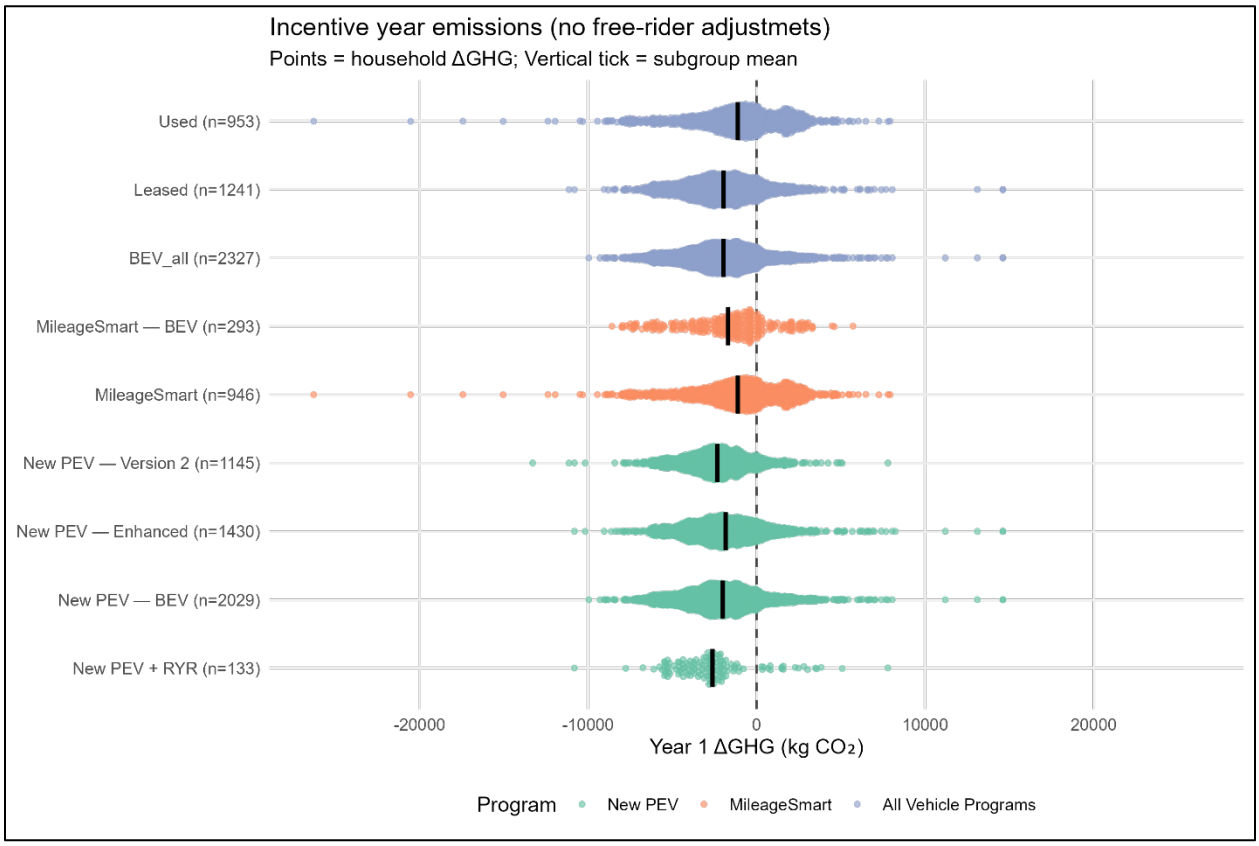

Figure 17 Predicted household GHG change in the year after receiving an incentive, before free rider adjustment

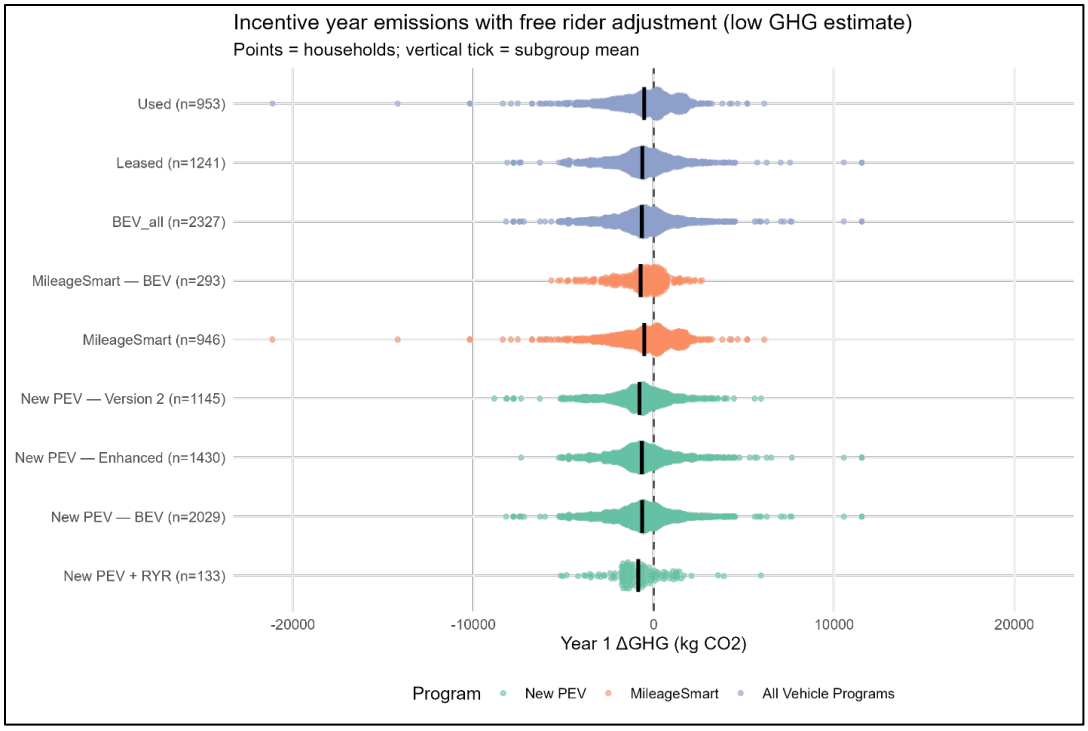

Figure 18 Predicted household GHG change in the year after receiving an incentive, with low GHG change free rider adjustment

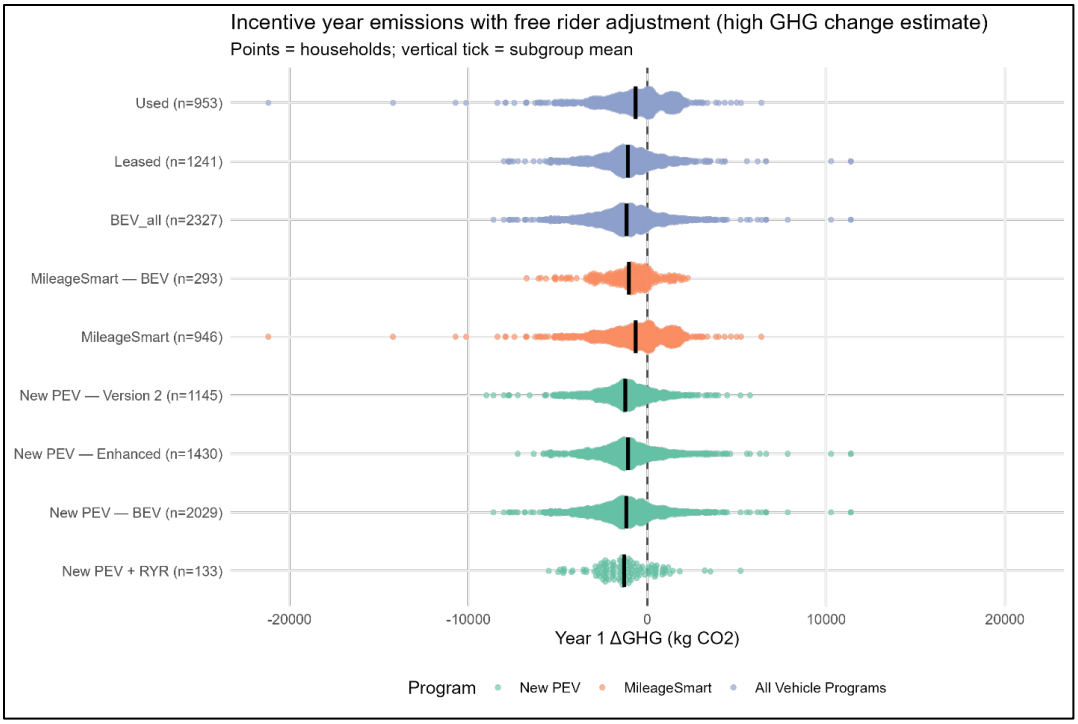

Figure 19 Predicted household GHG change in the year after receiving an incentive, with high GHG change free rider adjustment

APPENDIX G. INCENTIVE RECIPIENT CHARACTERISTICS

G.1 Uncorrected incentive recipient characteristics

As in Appendix F, plots that visualize VMT or GHG emissions require vehicles that have complete VMT data. **These samples are not corrected for bias and may not be representative of all incentive recipients.**

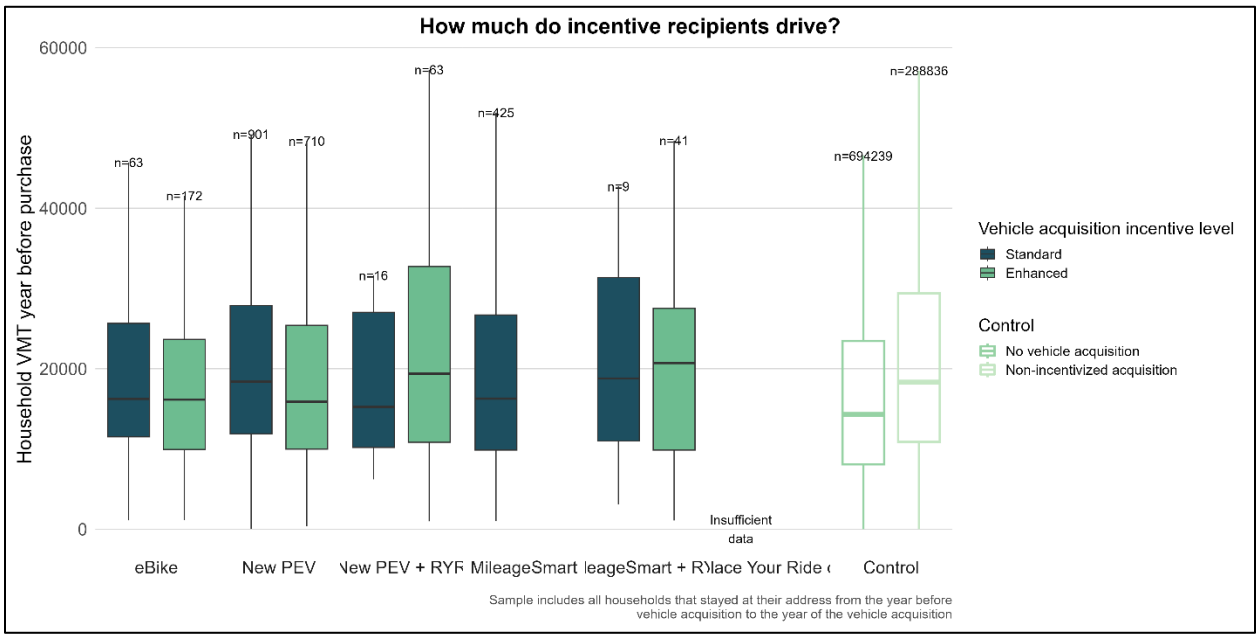

Figure 20 Household VMT of incentive recipients by program and level for households with complete data

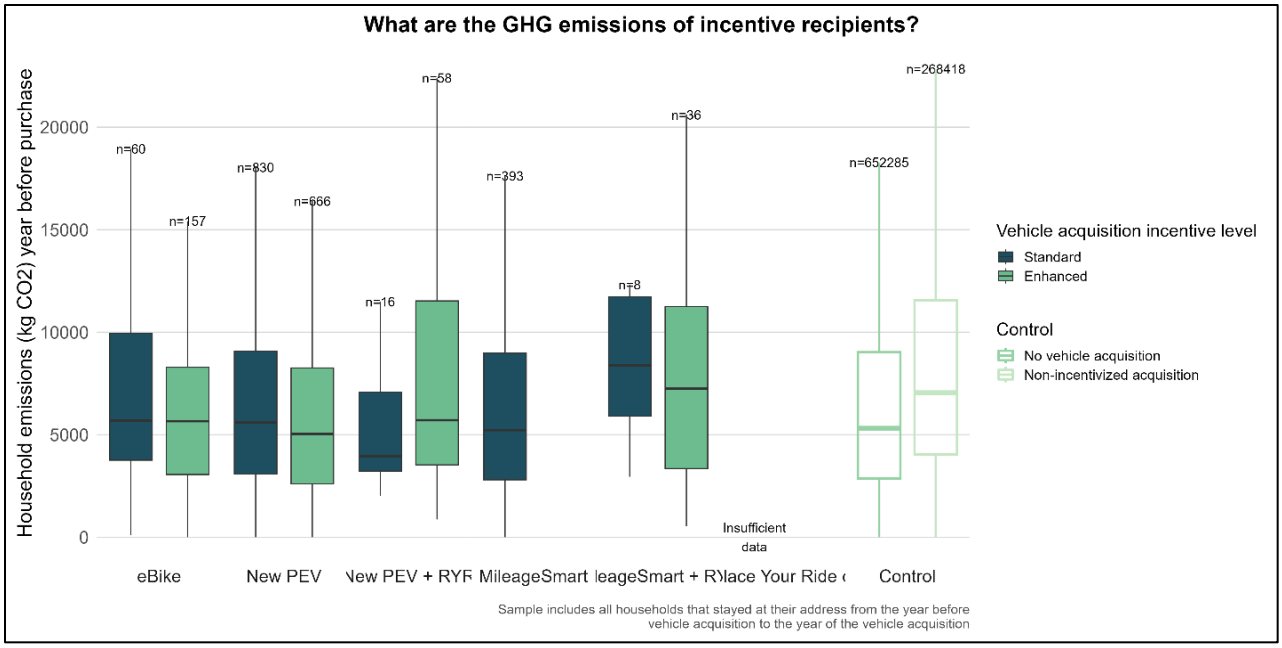

Figure 21 Household emissions of incentive recipients by program and level for households with complete data

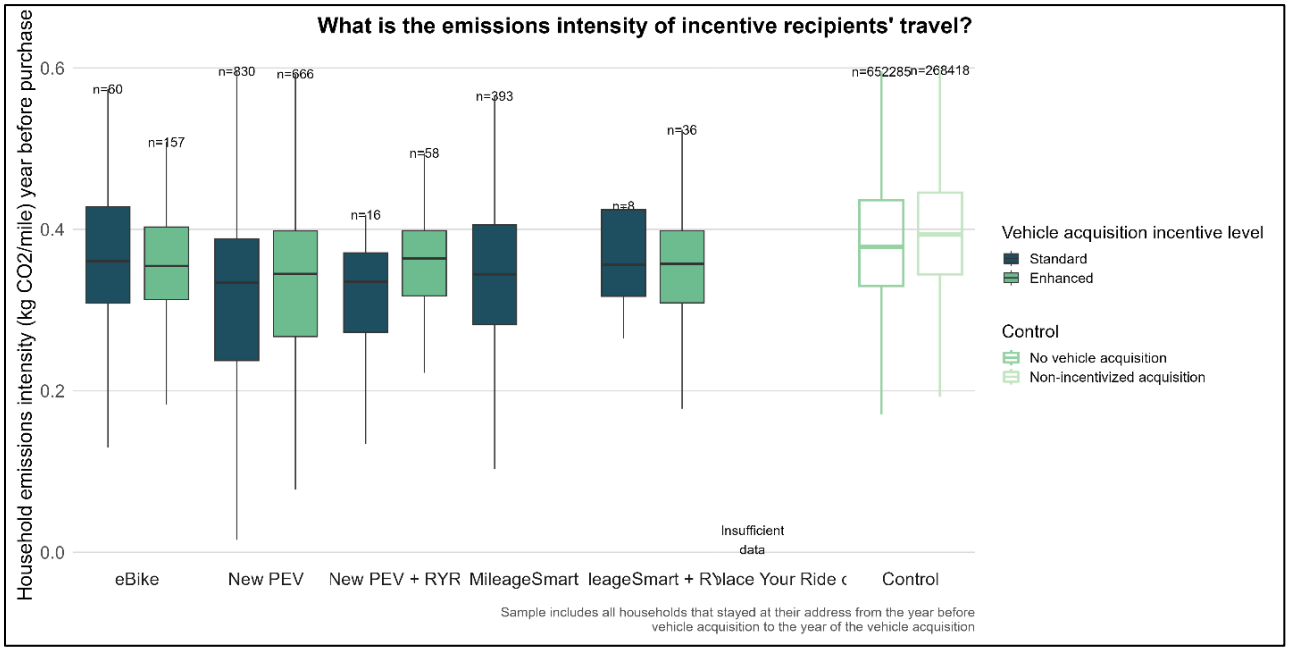

Figure 22 Emissions intensity of incentive recipients' household fleet by program and level for households with complete data

G.2 Comparison of trade-in vehicles to incentive vehicles

For incentive recipients that provided information on the vehicle they scrapped or sold ("prior vehicle") when acquiring their incentive vehicle, these plots display the VMT, emissions, and emissions intensity of i) the prior vehicle in the year before the incentive and ii) the incentivized vehicle during the first year after it was acquired.

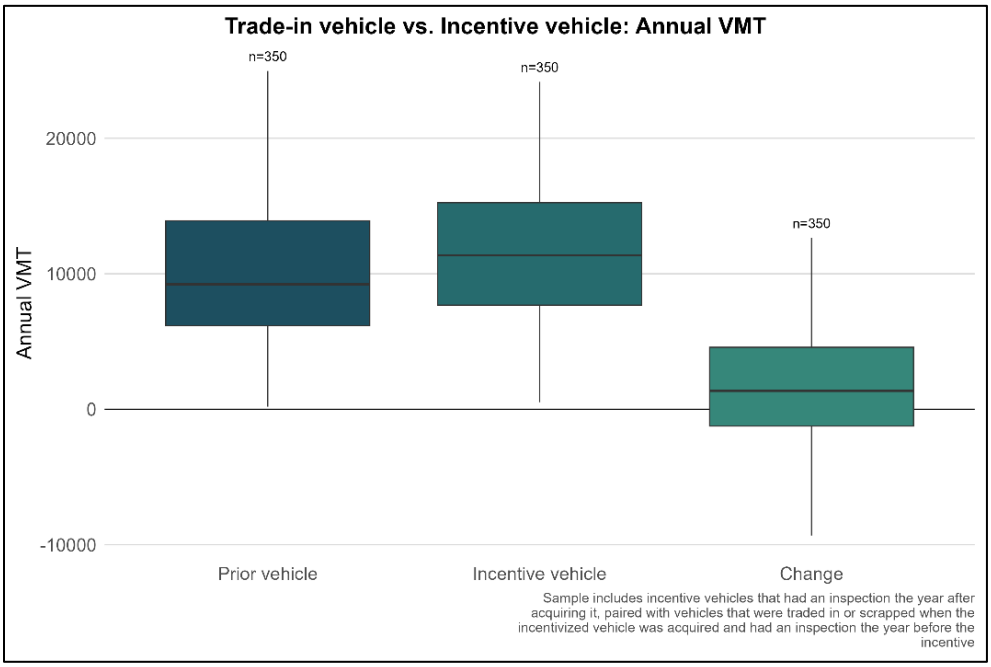

Figure 23 Annual VMT of traded/sold vehicles to that of the incentive vehicles that replaced them

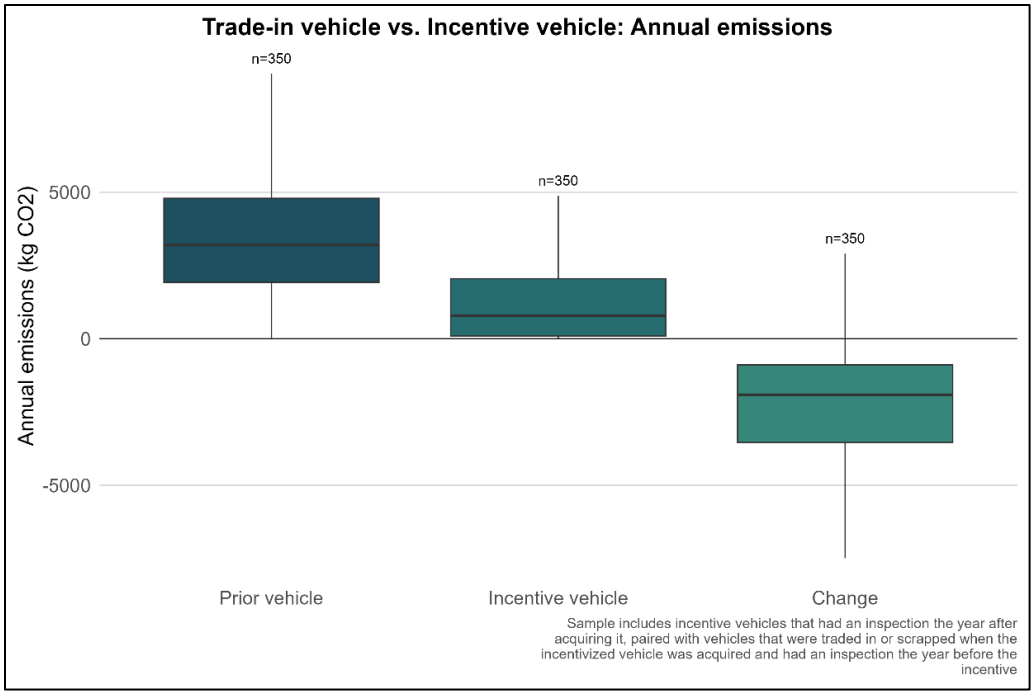

Figure 24 Comparison of annual emissions of trade-in/sold vehicles to that of the incentive vehicles that replaced them for vehicles that have complete data.

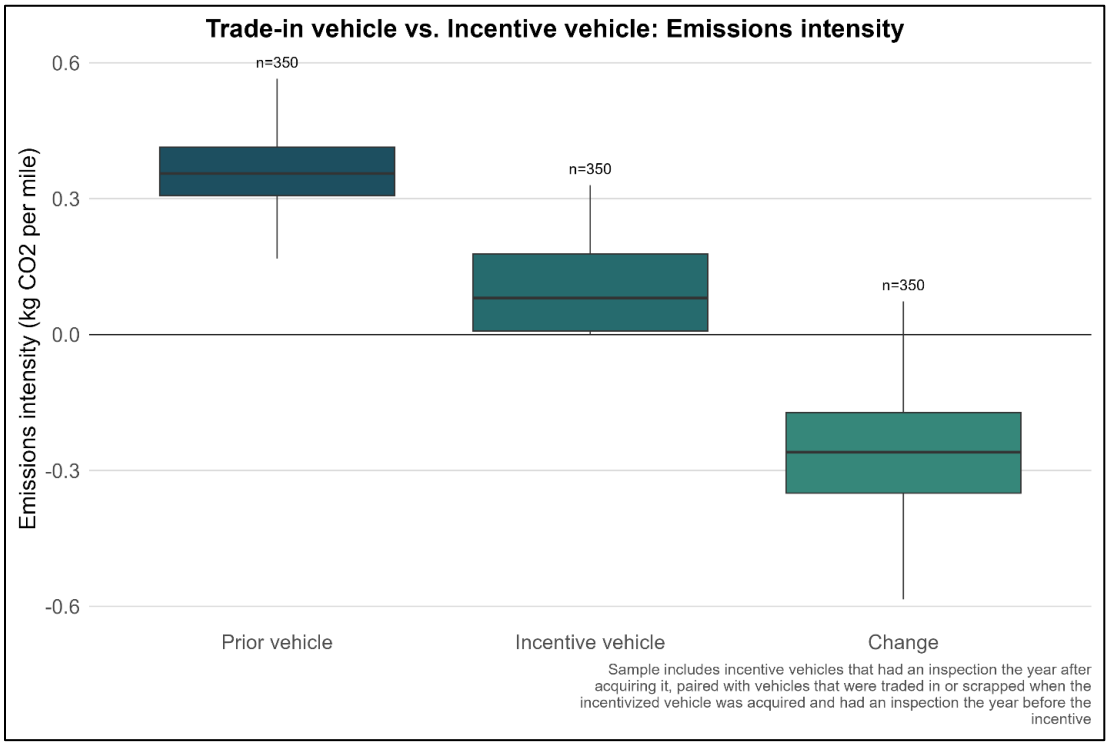

Figure 25 Comparison of emissions intensity of trade-in/sold vehicles to that of the incentive vehicles that replaced them for vehicles that have complete data.

G.3 Incentive recipient locations

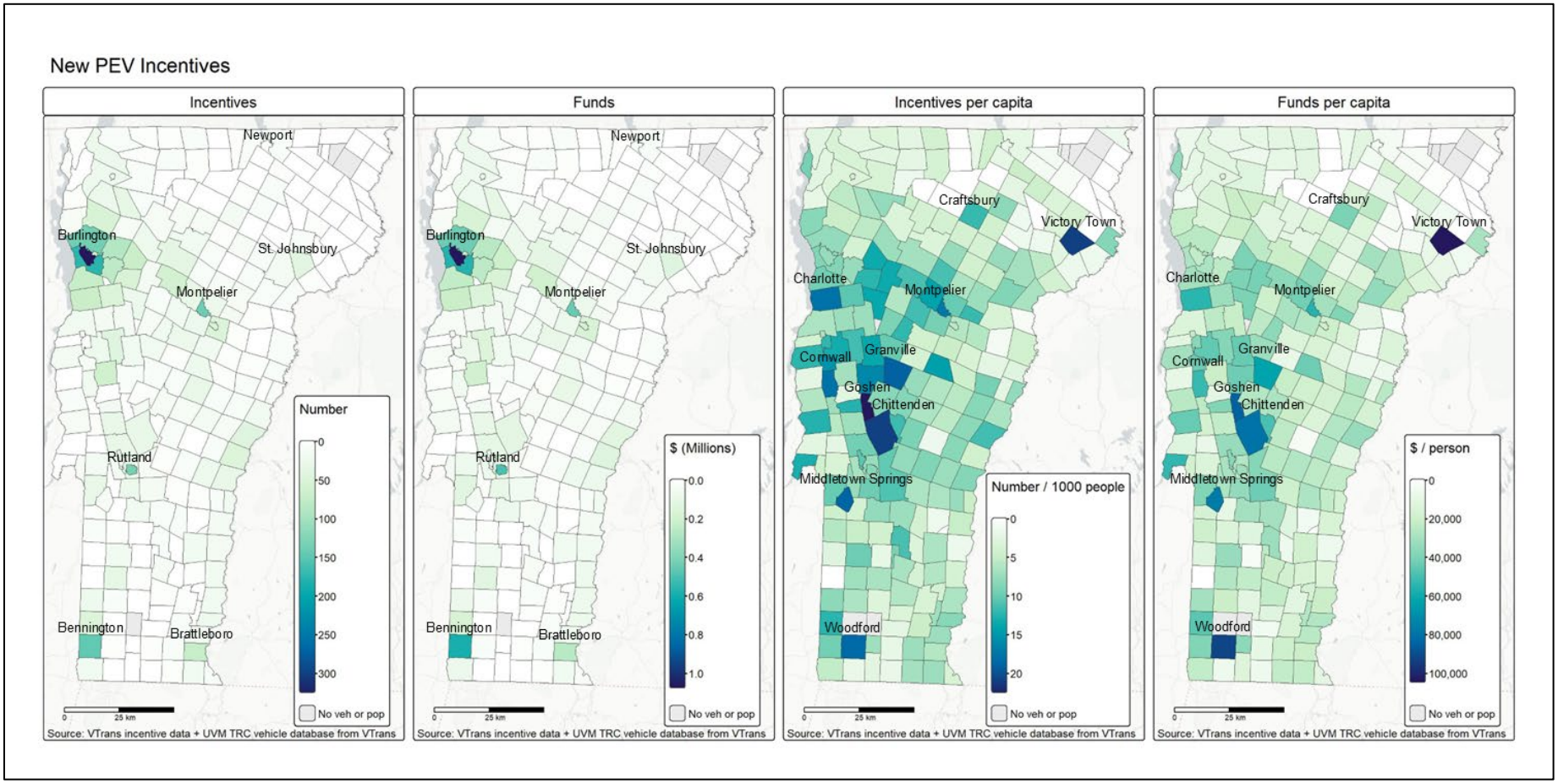

Figure 26 New PEV incentive recipients and funds in Vermont's municipalities

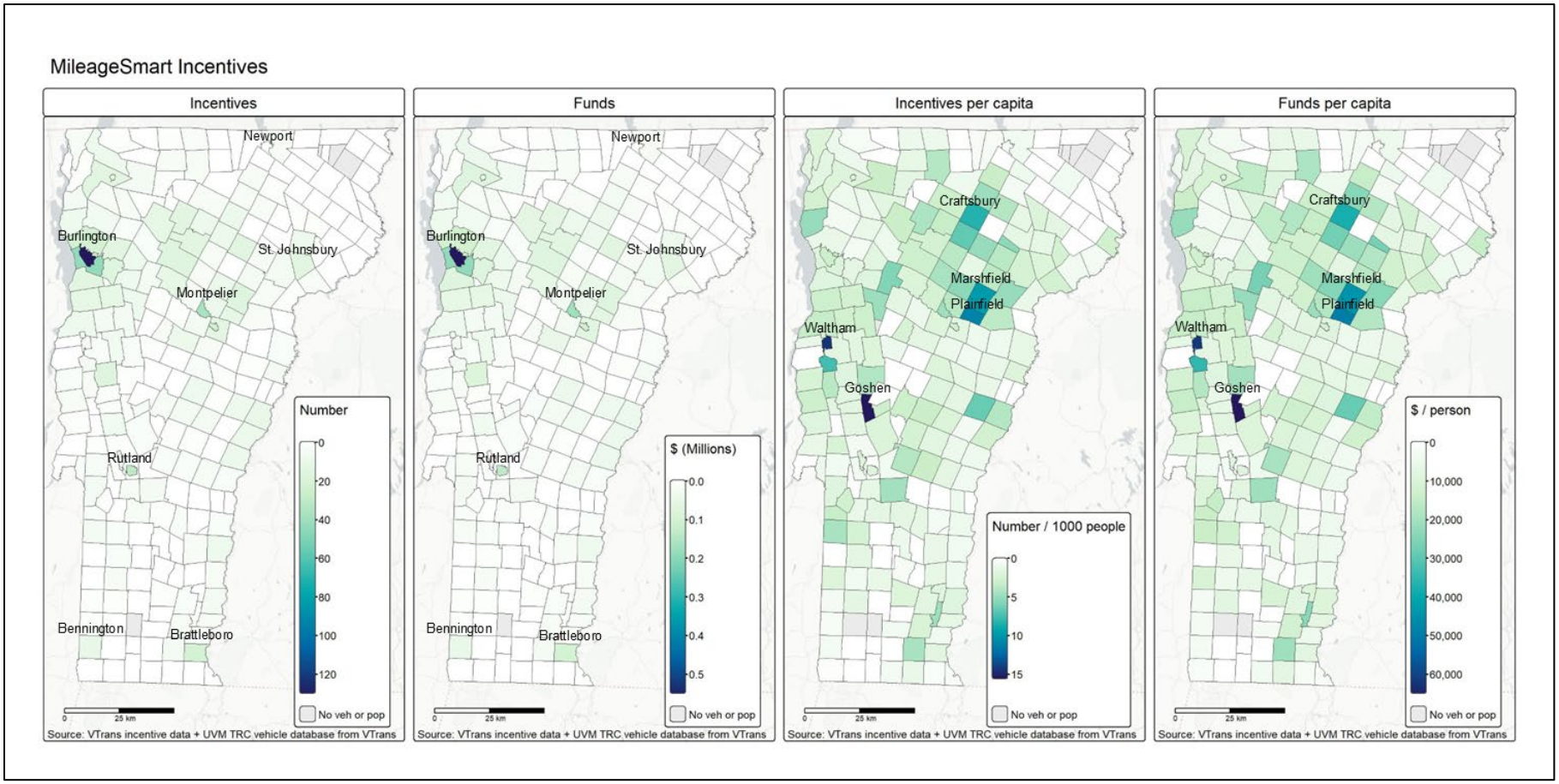

Figure 27 MileageSmart incentive recipients and funds in Vermont's municipalities.

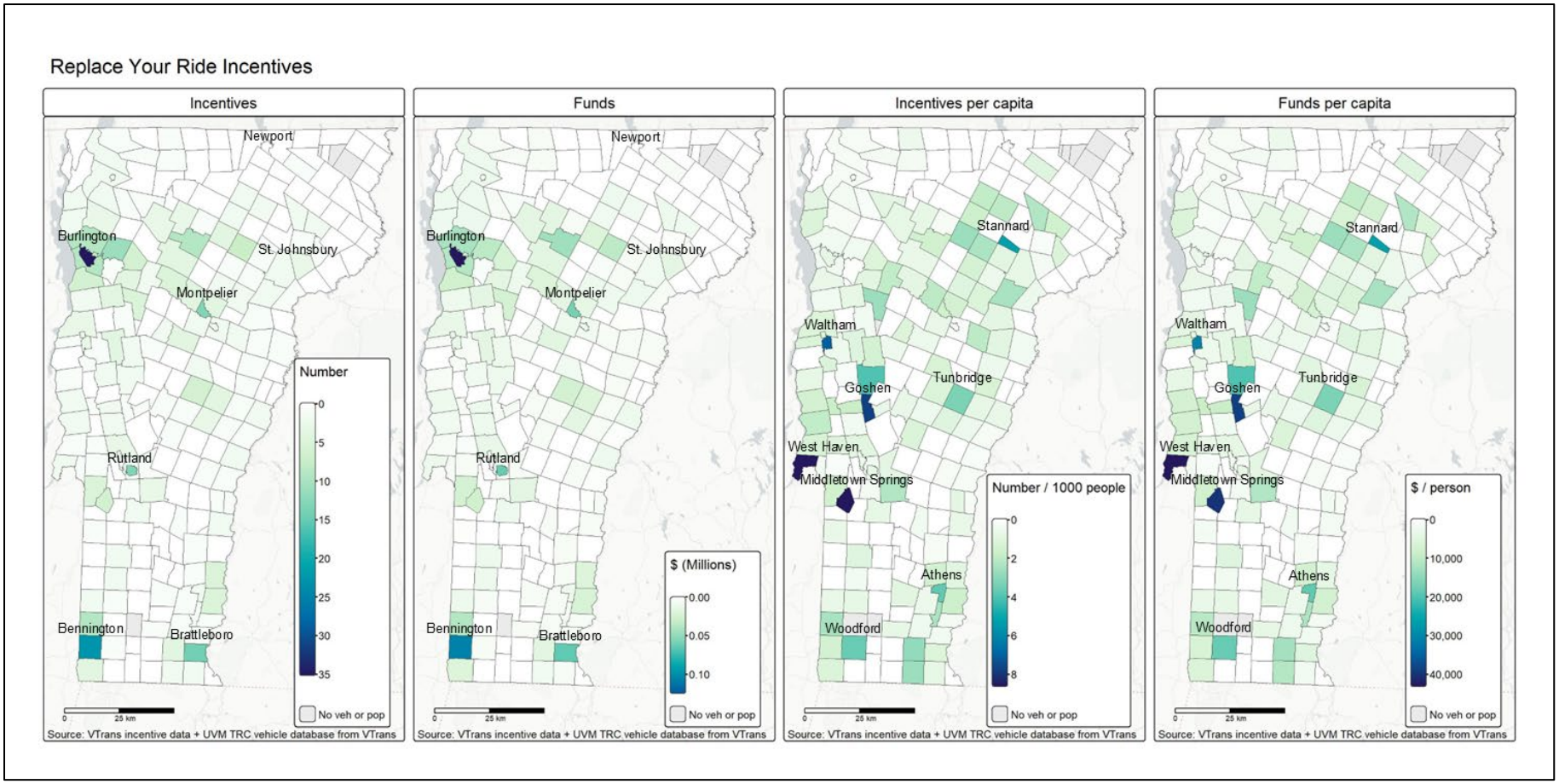

Figure 28 Replace Your Ride incentive recipients and funds in Vermont's municipalities.

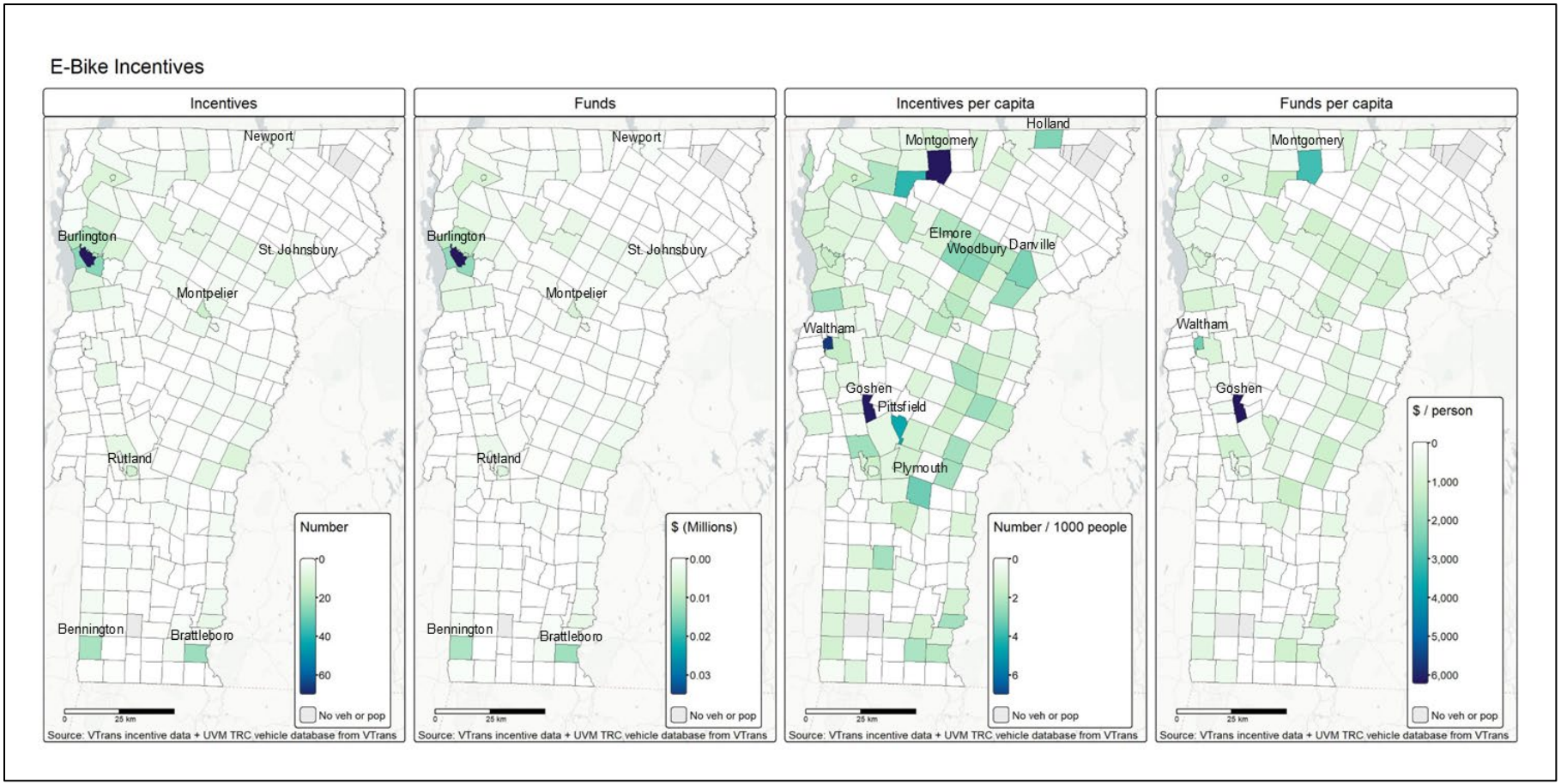

Figure 29 e-Bike incentive recipients and funds in Vermont's municipalities.

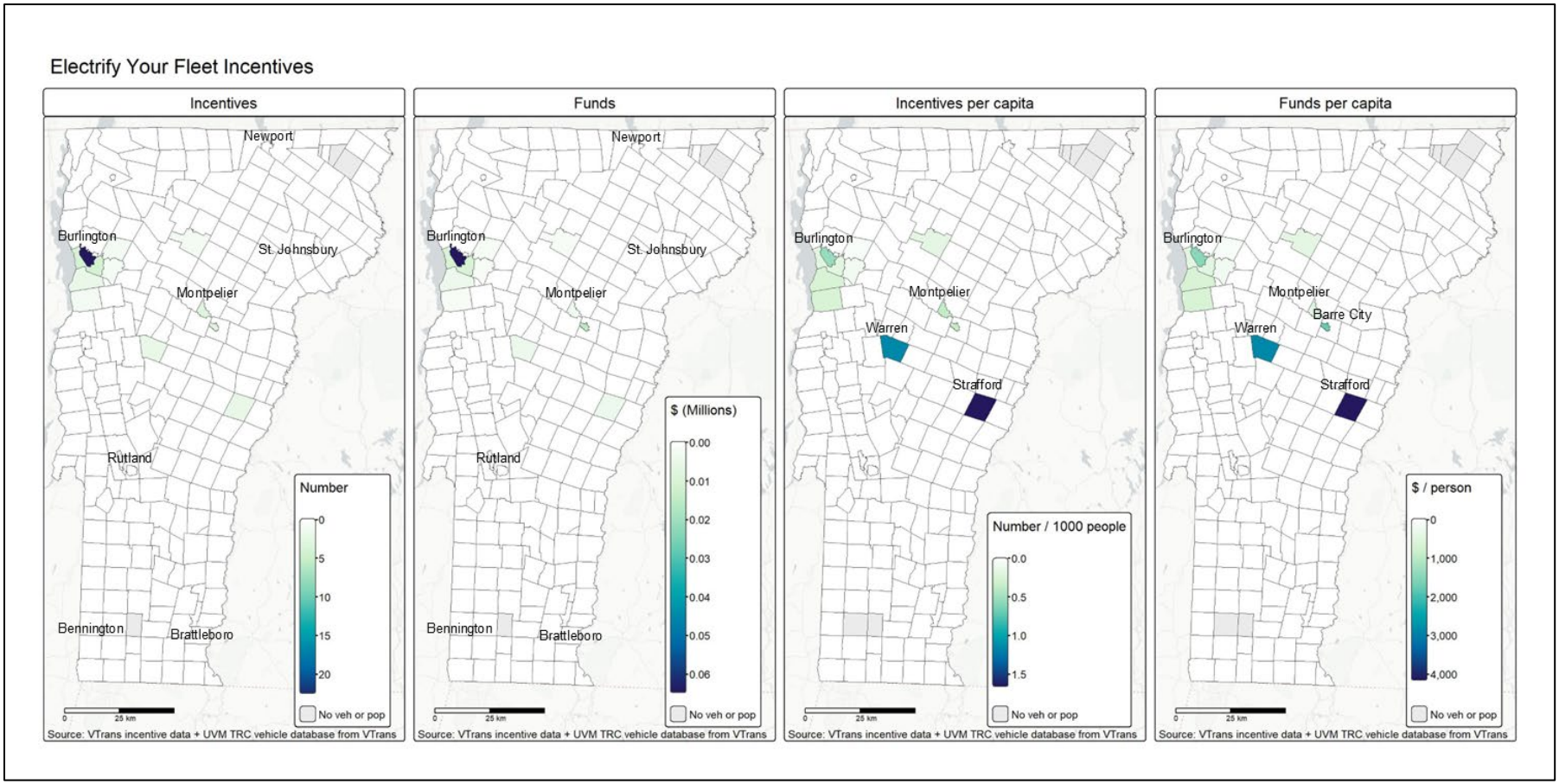

Figure 30 Electrify Your Fleet incentive recipients and funds in Vermont's municipalities.

APPENDIX H. PREDICTED LIFETIME HOUSEHOLD GHG CHANGE

The following visualizations show the predicted GHG change for incentive households. These results are adjusted for free riders and include the emissions that occur over the lifetime of incentivized vehicles. Results shown here include all data in the vehicle table, so represents results that are corrected for sample bias, consistent with the final results shown in the main report in Table 10. The subgroups shown are those for which we were able to generate robust predictions according to the 10% threshold for the difference between observed and predicted GHG change.

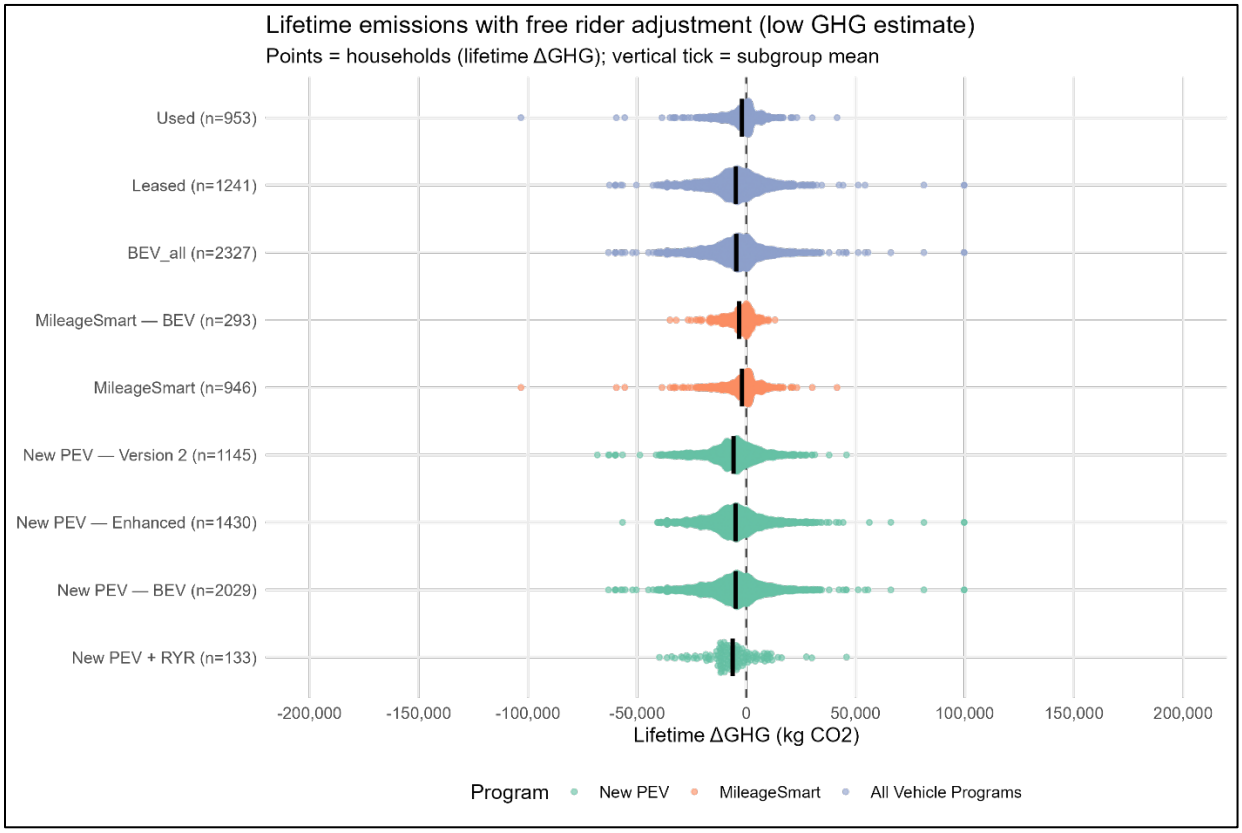

Figure 31 Predicted change in lifetime GHG emissions over an incentivized vehicle's lifetime (low estimate). Negative values indicate emissions savings.

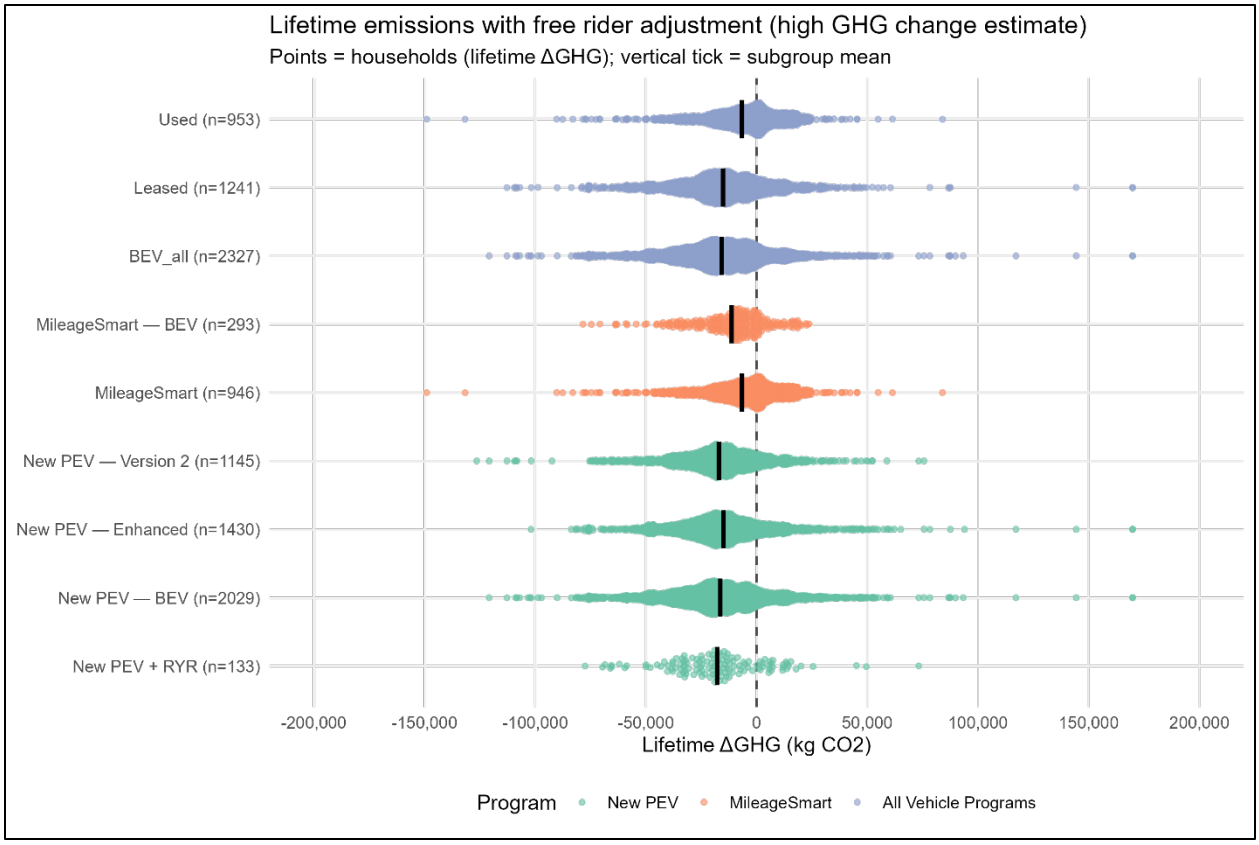

Figure 32 Predicted change in lifetime GHG emissions over an incentivized vehicle's lifetime (high estimate)