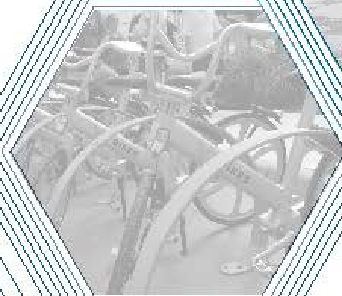

Equity Assessment of Plug-In Electric Vehicle Purchase Incentives with a Focus on Atlanta, Georgia

Haobing Liu, Ph.D.
Randall Guensler, Ph.D.
Michael O. Rodgers, Ph.D.

FINAL REPORT

Center for Transportation Equity, Decisions & Dollars

EQUITY ASSESSMENT OF PLUG-IN ELECTRIC VEHICLE PURCHASE INCENTIVES WITH A FOCUS ON ATLANTA, GEORGIA

FINAL PROJECT REPORT

By:

Haobing Liu, Ph.D.
Research Engineer II
School of Civil and Environmental Engineering
Georgia Institute of Technology

Randall Guensler, Ph.D.
Professor
School of Civil and Environmental Engineering
Georgia Institute of Technology

Michael O. Rodgers, Ph.D.
Regents Researcher and Adjunct Regents Professor
School of Civil and Environmental Engineering
Georgia Institute of Technology

Sponsorship:
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For:
Center for Transportation, Equity, Decisions and Dollars **(CTEDD)**
USDOT University Transportation Center
The University of Texas at Arlington
601 W.Nedderman Dr. Suite 103
Arlington TX 76019-0108 United States
Phone: 817-272-5138 | Email: C-Tedd@uta.edu

In cooperation with US Department of Transportation-Research and Innovative Technology Administration (RITA)

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To help consumers overcome higher initial purchase costs of plug-in hybrid and battery-electric vehicles (collectively PEVs), and to help promote PEV adoption, government agencies and electric utilities have offered a variety of purchase and leasing incentives over time. While the PEV population has grown rapidly since 2011, the PEV market share and the demographics of PEV users varies significantly within and across regions. This research examines the distribution of benefits associated with consumption of PEV incentives across demographic groups in the Metro Atlanta area. The recipients of the PEV incentives were identified and associated benefits were quantified using models, monitored data, and surveys. The accessibility of incentives across demographic groups was evaluated to identify the barriers to participation across household income and other demographic group(s), including eligibility and credit amounts. For example, the Federal's income tax credits for qualified PEV purchases were not accessible to many low-income household groups because credits could only be applied to taxes owed. A comparative analysis of socio-demographic characteristics of PEV users vs. non-PEV users was examined by household size and structure, income, etc. and, the differential impacts of PEV purchases on energy use and emission associated with replacement of conventional vehicles with PEVs were estimated. It was found that households with lower income or more children were less likely to be eligible for some or all of the federal PEV credit, ending up with 62.1% of households (59.2% of the population) in surveyed Atlanta Metro area that are not eligible for full federal PEV credit ($7,500). On the other hand, based on the in-field license plates investigation and emissions modeling results using MOVES-Matrix, vehicles from households with lower income levels produce higher emissions and would provide greater emission reduction benefits and energy savings if they were replaced with BEVs, assuming that daily vehicle use is comparable. However, these households are less likely to qualify for the full federal or state tax incentive. The study findings are expected to help decision-makers identify any potential distributive justice issues concealed within existing incentive policies.</td></tr>
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Abstract

To help consumers overcome higher initial purchase costs of plug-in hybrid and battery-electric vehicles (collectively PEVs), and to help promote PEV adoption, government agencies and electric utilities have offered a variety of purchase and leasing incentives over time. While the PEV population has grown rapidly since 2011, the PEV market share and the demographics of PEV users varies significantly within and across regions. This research examines the distribution of benefits associated with consumption of PEV incentives across demographic groups in the Metro Atlanta area. The recipients of the PEV incentives were identified and associated benefits were quantified using models, monitored data, and surveys. The accessibility of incentives across demographic groups was evaluated to identify the barriers to participation across household income and other demographic group(s), including eligibility and credit amounts. For example, the Federal's income tax credits for qualified PEV purchases were not accessible to many low-income household groups because credits could only be applied to taxes owed. A comparative analysis of socio-demographic characteristics of PEV users vs. non-PEV users was examined by household size and structure, income, etc. and, the differential impacts of PEV purchases on energy use and emission associated with replacement of conventional vehicles with PEVs were estimated. It was found that households with lower income or more children were less likely to be eligible for some or all of the federal PEV credit, ending up with 62.1% of households (59.2% of the population) in surveyed Atlanta Metro area that are not eligible for full federal PEV credit ($7,500). On the other hand, based on the in-field license plates investigation and emissions modeling results using MOVES-Matrix, vehicles from households with lower income levels produce higher emissions and would provide greater emission reduction benefits and energy savings if they were replaced with BEVs, assuming that daily vehicle use is comparable. However, these households are less likely to qualify for the full federal or state tax incentive. The study findings are expected to help decision-makers identify any potential distributive justice issues concealed within existing incentive policies.

Chapter I: Introduction

Plug-in electric vehicles (PEVs), including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), are promising options to achieving the goals of supporting greater energy security, reducing emissions, and providing price stability. Over the last decade, a number of incentives for purchasing, leasing, and using PEVs have been made available from federal government, state governments, and electric utility companies to address market barriers, and to help consumers overcome the incremental initial purchase and usage costs of PEVs compared to their conventional gasoline equivalents.

Since 2011, PEV sales in the United States have grown rapidly, corresponding to the widespread availability of market choices and the implementation of PEV incentives. In 2018, 14 BEV models (e.g., Nissan Leaf, Tesla Model 3, Tesla Model S) and 27 PHEV models (e.g., Chevrolet Volt, Toyota Plug-in Hybrid) were available in the U.S. market. The federal government, 23 states, and the District of Columbia offered incentives to promote PEV adoption. The most common purchase incentives include rebates, excise tax exemptions, and income tax credits. The Federal government provides up to $7,500 as a tax credit for the purchase of a new qualified PEV. As one of the pioneer states to promote BEV adoption in the United States, the state of Georgia provided up to $5,000 in state-level income tax credits for purchasing or leasing zero-emission vehicles, including battery electric vehicles (hybrid electric vehicles do not qualify as zero emission vehicles). The Georgia credit was terminated by the state legislature on June, 30th, 2015.

Most EV incentive studies in the literature have focused on the policy effectiveness of incentives on PEVs adoption. One of the earliest studies by Diamond (2009) examined the U.S. state-level incentives on hybrid electric vehicle (HEV) adoption from 2001 through 2007. The results showed a strong relationship between gasoline prices and hybrid vehicle purchase decisions. In contrast, other prior research indicates that the relationship between incentive policies and hybrid vehicle adoption is significant, but much weaker than the influence of gasoline price. Three research projects by Chandra, et al. (2010), Gallagher and Muehlegger (2011), and Beresteanu and Li (2011) all concluded that government incentives did show a positive and significant effect on the market share of HEVs. In recent years, with the growth of PEV market in the United States, additional studies have focused on the effectiveness of incentives on PEVs adoption. Jin et al. (2014) found that state-level PEV incentives significantly promote PEV sales and the states with the largest PEV incentives had the largest PEV sales share (approximately two to four times greater than the national average). However, Vergis, and Chen (2015) analyzed the U.S. 2013 market shares data and found that although incentives were correlated with PHEV market share, they were not for the BEV market share. Jenn et al. (2018) analyzed 2010-2015 state-level PEV monthly sales data, and concluded that average sales of EVs increase by 2.6% for every $1,000 offered as rebates to tax credits. The study also highlighted the importance of raising consumer awareness in the success of EV incentive programs. Wee, et al. (2018) analyzed data from the same period (2010-2015) and found that a $1,000 increase in the value of a state's model-specific EV policies increases registrations of that model within the state by 5% to 11%. Several studies highlighted that PEV adoption is greatest when multiple policies are implemented in parallel (Zhou et al., 2017; Zambrano-Gutiérrez et al, 2018).

However, another critical aspect of policy performance, social equity, has not been extensively explored (see Gao and Klein, 2010; Bills et al., 2012; Karner and Niemeier, 2013). In this study, the equity assessment will focus on *whether incentives have comparable accessibility to the public and provide comparably energy and emission-reduction benefits across income groups*. Several research efforts that have highlighted the potential equity issue of PEV incentives (Sheldon, DeShazo and Carson, 2015; Miller, 2018), but these studies did not focus on quantifying on how large the equity issue are by exploring the coverage of the benefits across difference household groups. Research has found that the influence of demographics on preferences for electric vehicles is significant, for example electric vehicle users tend to have higher income and education levels than the general population (Kodjak, 2012; Carley et al., 2013; Axsen et al., 2016; Sovacool et al., 2018). Given the cost and education barriers to purchase, it is important to explore how PEV incentive program benefits were distributed across the population.

With a focus on the Metro Atlanta area, the team will assess the equity implications of the PEV tax credit implemented in Georgia from federal and state level, using recent vehicle registration data, licensed household-level sociodemographic data, and monitored vehicle activity data. The available of these data make it an ideal time to examine the distribution of benefits from PEV incentives across demographic groups.

Chapter 2 will introduce the federal and state-level PEV incentives in the United States. Chapter 3 evaluate and compare credit accessibility for Federal, Georgia, and other states who have implemented income tax credits across sociodemographic household groups, including tax filing status, income, and number of children. Chapter 4 assesses the accessibility of PEV credit with a focus on the metro Atlanta area. Chapter 5 estimates the differences in emissions across demographic groups, including households with different levels of credit eligibility. Chapter 6 discusses the potential distributive justice aspects of the PEV incentive strategies as revealed by accessibility to incentives by traditionally underserved households. The study constitutes an attempt to conduct a detailed PEV incentive equity analysis, and is transferable to other regions in which the PEV credits have been made available.

Chapter II: Federal and State PEV Purchase Incentives

Incentives for purchasing or leasing PEVs come in forms of rebates, income tax credits, and excise tax exemptions. The federal and state level incentives that affect vehicle purchases and leasing decisions in Georgia are both in the form of income tax credits.

At the Federal level, a tax credit is available for the purchase of a new qualified PEV that draws propulsion using a traction battery that has at least 5 kWh of capacity, uses an external source of energy to recharge the battery (i.e., "plug-in"), has a gross vehicle weight rating of up to 14,000 pounds, and meets specified emission standards (see 26 U.S. Code 30D). The minimum credit is $2,500, and the maximum credit is $7,500, depending on each vehicle's traction battery capacity and the gross vehicle weight rating. The credit begins phasing out for each manufacturer in the second quarter following the calendar quarter in which a minimum of 200,000 qualified PEVs have been sold by that manufacturer for use in the United States. Tesla® and General Motors® (GM) were the first two manufacturers to reach their sales limit, with available maximum tax credit reduced in half to $3,750 from January 1st and April 1st of 2019. It is important to note that the federal incentive is only worth $7,500 to customers whose federal tax bill at the end of the year is $7,500 or more. For example, if a household that owes $4,500 in federal income tax purchases a Nissan Leaf or other eligible BEVs, the household only receives a $4,500 the tax credit. The $3,000 unused portion of the full credit is lost, and cannot be applied against the following year's taxes.

At the state level, Georgia provided a Zero Emissions Vehicle (ZEV) credit from January 2011 through July 2015, through state income tax (O.C.G.A. Section 48-7-40.16) for up to 20% of a BEV purchase cost, or $5,000, whichever was lower (the full $5,000 credit was almost always consumed). For the purpose of this credit, a ZEV is defined as a motor vehicle that has zero tailpipe and evaporative emissions, including pure electric vehicles and hydrogen fuel cell vehicles. The Georgia incentives did not apply to hybrid electric vehicles. Unlike the federal tax credit, the Georgia tax credit could be carried forward for up to five tax years, with maximum annual credit of $1,000.

In addition to Georgia, 23 other states have offered BEV purchase incentives and 22 states have offered PHEV purchase incentives (incentives for PHEVs also apply to BEVs). The incentive credits range from $500 in Montana for the purchase of qualified PEVs, up to a $4,500 rebate in California for the purchase of PEVs. A summary of purchase incentive programs implemented from January 2011 through December 2018 is presented in Table 1. There are 13 states (Arizona, California, Connecticut, Delaware, Hawaii, Illinois, Massachusetts, New York, Pennsylvania, Rhode Island, Tennessee, Texas, and Vermont) that have implemented rebate programs, where the state government provided cash rebate to individuals who purchased or leased qualify PEVs. Seven states (Colorado, Georgia, Louisiana, Montana, Oregon, South Carolina, and Utah) implemented state income tax credits, where credit is redeemed against state income tax that individuals owe. Four regions (District of Columbia, Maryland, New Jersey, and Washington) offered excise tax exemption for the qualified PEVs purchased. Between January 2011 and December 2018, four states adjusted their credit amounts or the rules of their programs (California, Connecticut, Tennessee, and Texas). Some of the rebate programs provided flat credits (Arizona, the first program in California, Hawaii, Illinois, Massachusetts, the first program in Tennessee, and Texas), while others provided incentives that vary by battery size (Connecticut, New York, Pennsylvania, and Rhode Island) or vehicle technology (Connecticut, Delaware, and the second program in Tennessee). California, Vermont, and Pennsylvania offer higher PEV rebate incentives to lower-income households, to help households with lower disposable incomes overcome their relatively higher purchase and leasing barriers. In states that offered an income tax credit, the credits are generally lower for those households with lower income level, because the credit is redeemed against state income tax owed, which will be a focus of this research. However, the tax credit in Colorado is a special case, as any excess tax is refunded to the taxpayer, and thus the eligible credit is equal across all individuals, independent of taxes owed. Details on the EV incentives are summarized by the U.S. Department of Energy (AFDC, 2020).

Table 1 – Summary of State-level PEV Purchase Incentives

State	Incentive Type	Eligible EV Type	Vary with Battery Size	Eligible for Purchasing or Leasing	Related to HH Income	Credit Amount	Start Date	End Date	Policy End Announcement Date
AR	Rebate	BEV, PHEV	N	Purchase	N	$2,500	April 2013	April 2018	-
CA	Rebate	BEV, PHEV	N	Purchase, lease	N	$2,500	Before January, 2011	October 2016	-
					Income↓, credit↑	Up to $4,500	November 2016	After December 2018	-
CO	Income tax	BEV, PHEV	N	Purchase, lease	N	$5,000 for purchase, $2,500 for lease	January 2017	After December 2018	-
CT	Rebate	BEV, PHEV	Y	Purchase, lease	N	Up to $3,000 for BEV, up to $2,000 for PHEV	August 2015	September 2018	-
						Up to $2,000 for BEV, up to $1,000 for PHEV	October 2018	After December 2018	-
DC	Tax exemption	BEV, PHEV	N	Purchase, lease	N	Varies with vehicle price	Before January 2011	After December 2018	-
DE	Rebate	BEV, PHEV	N	Purchase, lease	N	$3,500 for BEV, $1,500 for PHEV	November 2016	After December 2018	-
GA*	Income tax	BEV	N	Purchase, lease	Income↓, credit↓	Up to $5000	Before January 2011	July 2015	March 2015
HI	Rebate	BEV, PHEV	N	Purchase	N	$4,500	Before January 2011	April 2012	-
IL	Rebate	BEV, PHEV	N	Purchase	N	$4,000	Before January 2011	March 2015	-
LA	Income tax	BEV, PHEV	N	Purchase	Income↓, credit↓	Up to $2,500	May 2013	After December 2018	-
MA	Rebate	BEV, PHEV	N	Purchase, lease	N	$2,500	June 2014	December 2018	December 6, 2018
MD	Tax exemption	BEV, PHEV	N	Purchase, lease	N	Up to $3,000	July 2017	After December 2018	-
MT	Income tax	BEV, PHEV	N	Purchase	Income↓, credit↓	Up to $500	Before January 2011	After December 2018	-
NJ	Tax exemption	BEV	N	Purchase, lease	N	Varies with vehicle price	Before January 2011	After December 2018	-
NY	Rebate	BEV, PHEV	Y	Purchase, lease	N	Up to $2,000	March 2016	After December 2018	-
OR	Income tax	BEV, PHEV	N	Purchase, lease	Income↓, credit↓	Up to $750	Before January 2011	December 2011	-
PA	Rebate	BEV, PHEV	Y	Purchase, lease	Income↓, credit↑	Up to $2,500	Before January 2011	After December 2018	-
RI	Rebate	BEV, PHEV	Y	Purchase, lease	N	Up to $2,500	February 2015	July 2017	-
SC	Income tax	BEV, PHEV	Y	Purchase, lease	Income↓, credit↓	Up to $2,000	May 2012	December 2016	September 2016
TN	Rebate	BEV, PHEV	N	Purchase, lease	N	$2,500	May 2011	June 2013	-
						$2,500 for BEV, $1,500 for PHEV	June 2015	April 2016	-
TX	Rebate	BEV, PHEV	N	Purchase, lease	N	$2,500	May 2014	June 2015	-
							June 2017	After December 2018	-
UT	Income tax	BEV, PHEV	N	Purchase, lease	Income↓, credit↓	Up to $1,500 for BEV, up to $1,000 for PHEV	April 2016	December 2016	August 2016
VT	Rebate	BEV, PHEV	N	Purchase, lease	Income↓, credit↑	Up to $1,800 for BEV, up to $1,500 for PHEV	June 2017	After December 2018	-
WA	Tax exemption	BEV, PHEV	N	Purchase, lease	N	Varies with vehicle price	June 2015	May 2018	May 2, 2018

** Georgia is the only state that allows the state income tax credit to be carried forward for five consecutive tax years starting from purchase year.*

Chapter III: Tax Credit Income Threshold and Eligibility

An estimation of a household's income tax liability at both federal and state levels is required to quantify the amount of total incentive to which a household is eligible (i.e., their incentive accessibility). For example, a federal tax credit of up to $7,500 and a Georgia tax credit of up to $5,000 may have available for a BEV purchase, but these credits were accessible only to household that owed taxes greater than these amounts. This chapter introduces the approach used to estimate income tax liability, and eligibility for federal and state level income tax credits implemented in recent five years in the United States, including the Federal income tax credit, and the Georgia, South Carolina, Utah, Louisiana, and Montana state income tax credits. State credits can be classified into two groups (Table 2): Group 1 includes Georgia, South Carolina, and Utah, where the state income tax and credits are independent of federal tax liability; Group 2 includes Louisiana and Montana which involve a federal non-refundable tax liability deduction, thus the state income tax credit depends on federal tax liability. Furthermore, the number of children affects the Group 2 state tax credit. More details on the difference of these two groups are presented in separate sections in this Chapter.

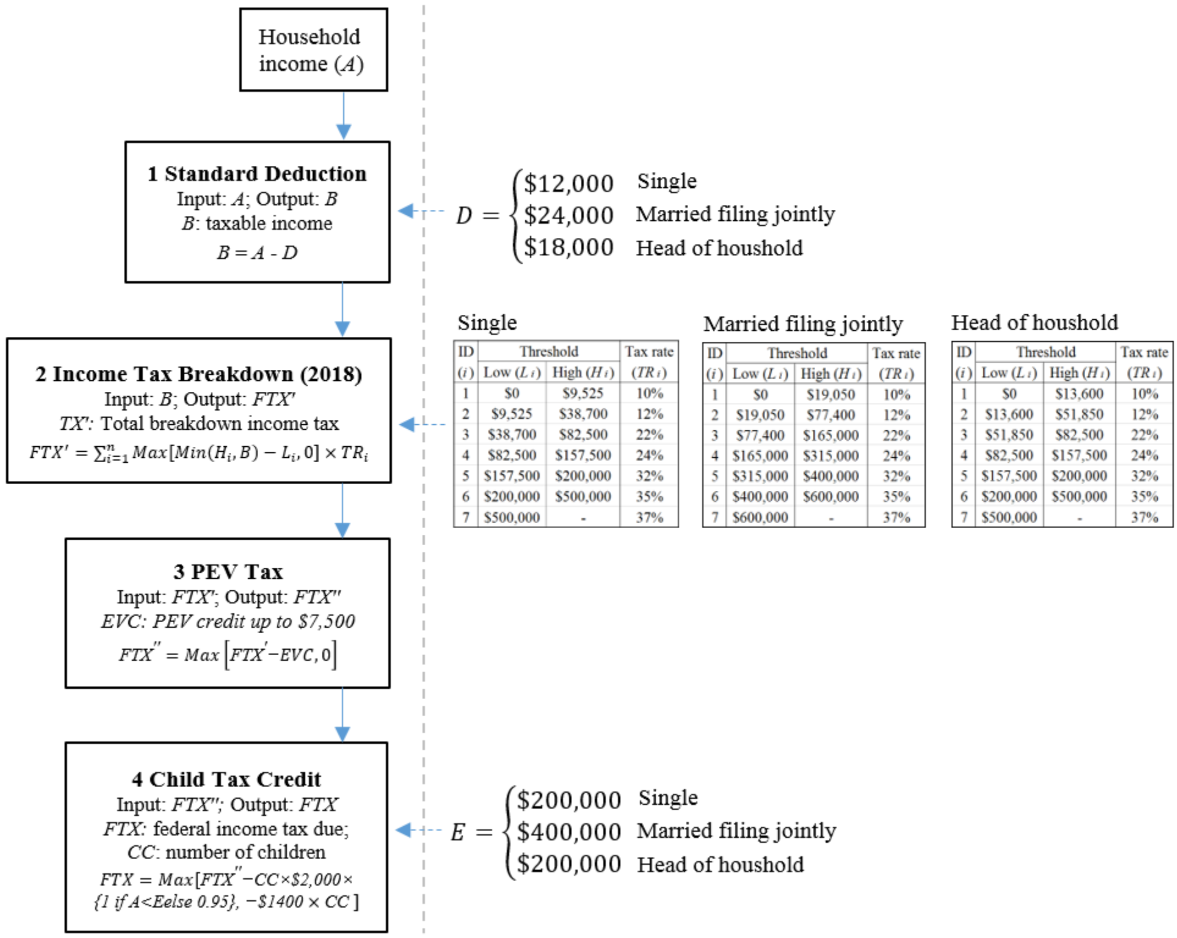
Table 2 – Two State Tax Groups Explored

State Group	Federal Tax Liability Deduction	Depends on Number of Children
Group 1: Georgia, South Carolina, Utah	No	No
Group 2: Louisiana, Montana	Yes	Yes

3.1 Estimation Approach for Income Tax and Eligibility for PEV Credit

The research team explored tax credit policies in 2018, and developed a Python^{TM}-based script to calculate taxes due based on the household's income, number of children, and tax filing status. This software was updated for use in this analysis, in which the research team specifically investigated three tax filing status types: Single (S), Married Filing Jointly (MJ), and Head of Household (HH). The team has left Married Filing Separately (MS) and Qualifying Widow(er) with Dependent Child (WD) filing status for future researchers to assess.

The federal income tax estimation process contains four steps, with dataflow presented in Figure 1. First, taxable income (B) is obtained from household income (A) minus a standard deduction (D), which varies by tax filing status. Second, taxable income is taxed using the progressively increasing rates that depend on the filing status and income level. As income increases, the income tax rate increases for that next income band. That is, each tax rate applies only to the income within each specific tax bracket. If a taxpayer earns enough to reach the next tax bracket and higher tax rate, only the income in the higher bracket is taxed at the higher rate. Hence, the total breakdown income tax (TX') is the sum of the taxes from each bracket. Third, the federal income tax credit is applied to deduct the TX' by up to $7,500. Finally, a child tax credit is applied for $2,000 per qualifying child 16 or younger at the end of the calendar year. If the credit exceeds taxes owed, families may receive up to $1,400 per child as a refund. The credit is reduced by five percent (5%) of adjusted gross income over $200,000 for single parents ($400,000 for married couples). The final federal tax, labeled as FTX, is positive representing dues, and negative for refund.



Single

ID (i)	Threshold Low (L_i)	High (H_i)	Tax rate (TR_i)
1	$0	$9,525	10%
2	$9,525	$38,700	12%
3	$38,700	$82,500	22%
4	$82,500	$157,500	24%
5	$157,500	$200,000	32%
6	$200,000	$500,000	35%
7	$500,000	-	37%

Married filing jointly

ID (i)	Threshold Low (L_i)	High (H_i)	Tax rate (TR_i)
1	$0	$19,050	10%
2	$19,050	$77,400	12%
3	$77,400	$165,000	22%
4	$165,000	$315,000	24%
5	$315,000	$400,000	32%
6	$400,000	$600,000	35%
7	$600,000	-	37%

Head of houshold

ID (i)	Threshold Low (L_i)	High (H_i)	Tax rate (TR_i)
1	$0	$13,600	10%
2	$13,600	$51,850	12%
3	$51,850	$82,500	22%
4	$82,500	$157,500	24%
5	$157,500	$200,000	32%
6	$200,000	$500,000	35%
7	$500,000	-	37%

Figure 1 – Data Flow of Federal Income Tax Estimation in 2018 (IRS, 2020)

The following examples show how the federal income tax is estimated given the family composition and filing status, with or without PEV credit. In each example, the research team implemented the equations described above and then confirmed the tax calculations using TurboTax federal and state software for each scenario.

Example A.1: A married couple has two children and qualifies for child credits of $2,000 per child. The total income is ***A = $150,000*** *in the year 2018. They* *purchased a new 2018 Nissan Leaf that qualifies for the **EVC = $7,500** tax credit. After the standard deduction (**D = $24,000** for married filing jointly) the resulting federal tax is, **FTX' = $19,599**. The family is fully eligible for PEV incentive ($7,500) and child credit ($2,000×2 = $4,000), and the final federal tax due is **FTX = $8,099**.*

*Example A.2: The same family as in Example A.1 did not buy a new 2018 Nissan Leaf and so is not qualified for the **EVC = $7,500** tax credit. After the standard deduction (**D = $24,000** for married filing jointly), the federal tax is, **FTX' = $19,599**. The family is fully eligible for* the $4,000 child credit, so the final federal tax due is ***FTX = $15,599***.

The tax difference between example A.1 and A.2 is the full amount of PEV tax credit: $7,500. As mentioned above, it is important to notice that the PEV credit are non-refundable and can only be claimed through tax owed. In contrast, the child tax credit is refundable for up to $1,400 per child. Also, the child credit is applied on top of PEV credit, the eligibility of these two credits are not completely independent from each other. The comparison between the two examples shows the interaction:

*Example B.1: A married couple with two children and qualifies for child tax credits of $2,000 each. The total income is **A = $90,000** in 2018. They also bought a new 2018 Nissan Leaf that qualifies for the **EVC = $7,500** tax credit. After the standard deduction (**D = $24,000** for married filing jointly), the federal tax is **FTX' = $7,539**. The family is fully eligible for PEV incentive ($7,500) making the federal tax due after this credit, **FTX" = $39**.* Because the $4,000 child credit would consume all of the remaining federal tax due, the family are eligible to obtain refund of up to $1,400 × 2 = $2,800. That is, ***FTX = -$2,800*** (a refund). *This means that the family obtained the full of PEV credit and a portion of the child credit ($2,800 + $39=$2,839), instead of the full $4,000).*

*Example B.2: The same family in Example B.1 did not buy a new 2018 Nissan Leaf and so not qualified for **EVC = $7,500** tax credit. After standard deduction (**D = $24,000** for married filing jointly) and break down tax calculation, the federal breakdown tax, **FTX' = $7,539**. The family is fully eligible for* the $4,000 child credit, so the final federal tax due, ***FTX = $3,539***.

Although this family was able to claim the full amount of PEV credit on their tax return, the application of PEV credit consumed most of the taxes due, leaving less room for claiming the full child credit. We quantify the net impact of the PEV credit as the difference between final tax due with and without PEV credit (step 3), which, in this case, is: $3,539 –

($2,800) = $6,339. Mathematically, the eligibility of PEV tax credit C_{PEV} is calculated in Eq 1:

$$C_{PEV} = |FTX_{EVC} - FTX_{no\ EVC}| \quad \text{Eq 1}$$

where FTX_{EVC} refers to the final federal income tax due with the PEV credit applied (e.g., example A.1 and B.1), and $FTX_{no\ EVC}$ refers to the income tax due without PEV credit (e.g., example A.2 and B.2).

3.2 Federal Tax Credit Eligibility

The tax estimation process presented in Section 3.1 is completely reversible, and enables the team to identify the household income threshold eligibility to obtain 100% of the $7,500 PEV credit, 50% of the credit ($3,750, Phase I cutoff), 25% of the credit ($1,875, Phase II cutoff), and income levels that do not qualify for any credits, as a function of filing status and number of children. The income thresholds for different federal credit levels are presented in Figure 2 A-1 (S), B-1 (MJ), and C-1 (HH):

- Households in the annual income and number of children scenarios that fall into the dark green area are eligible for the full $7,500 credit.
- Households that fall into the light green area are eligible for 50%-100% of the credit.
- Households that fall into the yellow area are eligible for 25%-50% of the credit.
- Households that fall into the pink area are eligible for 0%-25% of the credit.
- Households that fall into the red area do not qualify for any credit.

Figure 2 A-2 (S), B-2 (MJ) and C-2 (HH) present more details on the proportion of eligible credit for household matrices by number of children (from 0 to 9) and income (from $10,000 to $120,000 in $10,000 intervals). Figure 2 demonstrates that households with higher income and fewer children are more likely to be eligible for a greater share of the federal PEV credit. We consider general cases for households that have up to nine children and qualify for child tax credits (i.e., 16 years old or younger): a single (S) household's threshold income for full credit increases almost linearly from $64,600 to $89,100 per year as the number of children increases from 0 to 9. The threshold range is $89,700-$120,000 for married filing jointly (MJ) households, and $77,000-$102,000 for head of household (HH) filing status. The income range that qualifies for only 50% of federal PEV credit ranges from $44,900-$72,000 for single filing status, $58,400-$10,300 for MJ, and $51,500-$84,400 for HH, as the number of children increases from 0 to 9. The color gradient area (corresponding to the area between "100%" and "no credit" income threshold curve) in Figure 2 A-2 (S), B-2 (MJ) and C-2 (HH) also indicate sensitive income ranges that lead to significant changes in PEV eligibility.

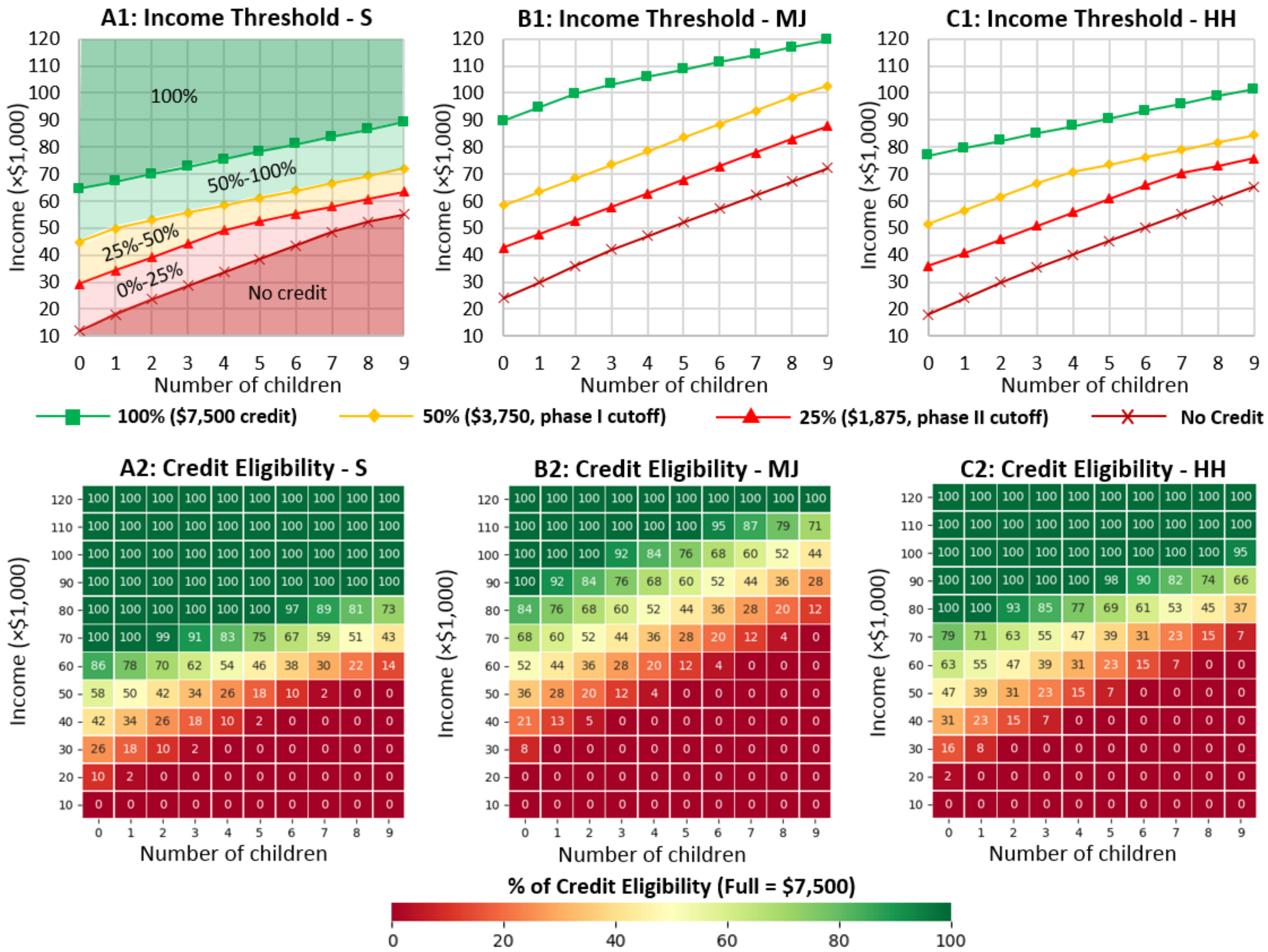


Figure 2 – Income Threshold and Eligibility for Federal Credit, A: Single (S), B: Married Filing Jointly (MJ), C: Head of Household (HH)

3.3 State Group 1 – Georgia, South Carolina and Utah Tax Credit

Estimation for Georgia, South Carolina, and Utah state level income tax and credit eligibility are conducted using the same procedures with state deductions and tax rates. Compared to federal taxes, state taxes are easier to model and display graphically in the figures that follow, because the states do not provide a refundable child tax credit. Single filing status and HH status also use the same tax rate in all of these states. Figure 3 shows the data flow of Georgia state income tax estimation in calendar year 2018. The same steps are applied for South Carolina and Utah, with their state-specific deductions and tax rates. The data flow for South Carolina and Utah are presented in Figure A-1 and Figure A-2 of Appendix 1.

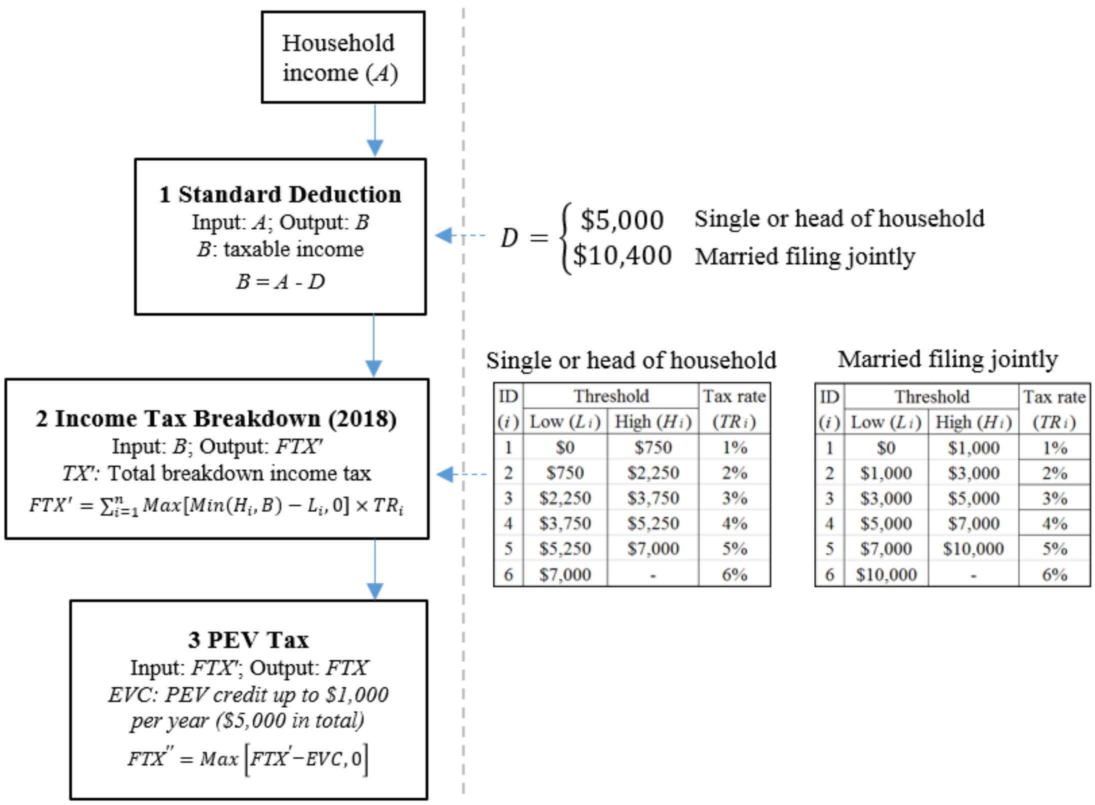


Figure 3 – Data Flow of Georgia State Income Tax Estimation in 2018 (Georgia DOR, 2020)

The income threshold and eligibility for Georgia, South Carolina, and Utah state EV credit can also be reverse engineered using the state tax estimation steps, applying Eq 1, and comparing results with the full state credit. Figure 4, Figure 5 and Figure 6 presented the tax eligibility for different household income levels, and the income threshold for full credit, 50%, 25%, and "no credit" cases in these three states, with the threshold values summarized and compared in Table 3.

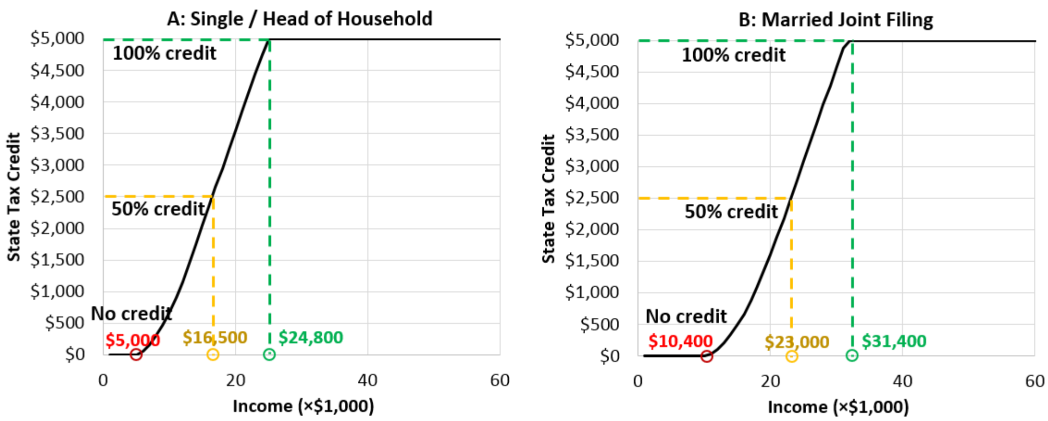


Figure 4 – Income Threshold and Eligibility for Georgia State Credit, A: Single (S) Head of Household (HH), B: Married Filing Jointly (MJ)

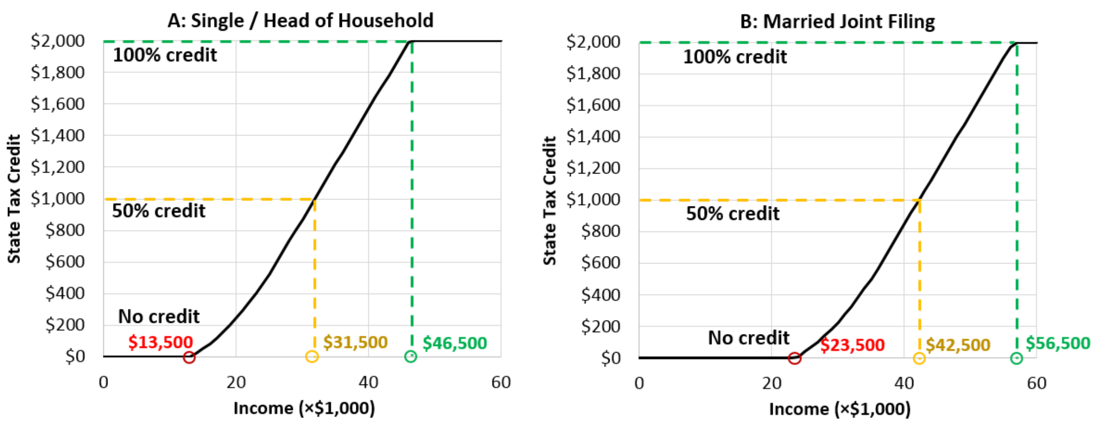


Figure 5 – Income Threshold and Eligibility for South Carolina State Credit, A: Single (S) Head of Household (HH), B: Married Filing Jointly (MJ)

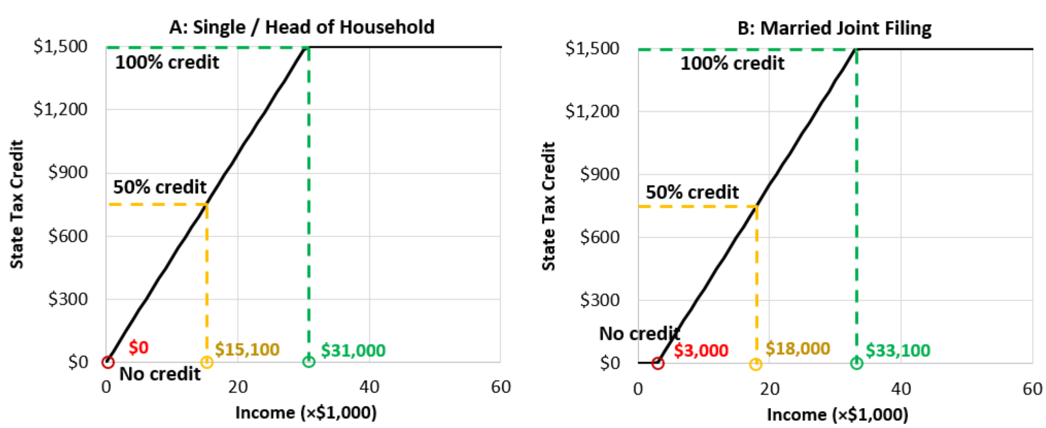


Figure 6 – Income Threshold and Eligibility for Utah State Credit, A: Single (S) Head of Household (HH), B: Married Filing Jointly (MJ)

As expected, states with higher EV credit values and lower state tax rates (corresponding to lower tax liability, or less tax deduction to be used for EV credit) require higher income threshold for credit eligibility. However, it is counter-intuitive to see the income threshold for the $5,000 credit in Georgia ($24,800) and the $1,500 credit in Utah ($31,000) are so much lower than for the $2,000 credit in South Carolina ($46,500). The income threshold for Utah is the lowest for 50% and lower credit eligibility, this is mainly due to the relatively high and flat tax rate applied in Utah tax policy. However, another important factor is the Georgia policy that allows the Georgia tax credit to be carried forward for up to five tax years, with a maximum annual credit of $1,000. In other words, the majority of households in Georgia who have more than in $1,000 state tax liability per year can claim the full $5,000 credit over five years. In contrast, the $2,000 South Carolina and $1,500 Utah incentive is only carried forward in the year that vehicle is purchased, and the unused portion of the credit can't be applied against the following year's taxes.

Table 3 – Summary of Income Threshold for Georgia, South Carolina and Utah Credit

State	Full Credit	Annual Income Threshold Single and HH			
		100% credit	50% credit	25% credit	No credit
Georgia	$5,000 ($1,000 per tax year)	$24,800	$16,500	$12,500	$5,000
South Carolina	$2,000	$46,500	$31,500	$24,700	$13,500
Utah	$1,500	$31,000	$15,1004	$7,600	$0
State	**Full Credit**	**Annual Income Threshold for MJ Status**			
		100% credit	**50% credit**	**25% credit**	**No credit**
Georgia	$5,000 ($1,000 per tax year)	$31,400	$23,000	$18,500	$10,400
South Carolina	$2,000	$56,500	$42,500	$35,000	$23,500
Utah	$1,500	$33,100	$18,000	$10,500	$3,000

In the Chapter 4, the research team will utilize Atlanta demographic database to evaluate the accessibility of Federal and Georgia credit. Although the demographics for other states are not available for this research, it is surprising if there are higher portion of households that are eligible for state credit in Utah than Georgia and South Carolina, due to the lower income threshold.

3.4 State Group 2 – Louisiana and Montana Tax Credit

The estimation of state tax and credit eligibility for two states in group 2: Louisiana and Montana, are more complicated than the states in group 1, mainly due to the existence of a federal tax deduction. That is, these states allow residents to take a deduction from state income for the federal taxes that they paid. If a household receives a federal tax deduction, that amount is no longer deducted from their state income, increasing their state tax liability. Figure 7 presents the data flow for Louisiana state tax estimation. The estimation of Montana state taxes follows very similar steps, with data flow in Figure A-3 of Appendix 1. Given the households income, the non-deductible federal tax liability is added back in (i.e., if there is refund, or D' < 0, set as zero) after the federal tax credit is estimated using the federal tax estimation process in Figure 1. This liability value along with state standard deduction are then subtracted from income before the calculation of the state tax liability (see step 1 and step 2 in Figure 7 and Figure A-3). Hence, the state tax liability and the state tax credit associated with the EV purchase are accounted for in the calculations. The following two examples can better illustrate this impact.

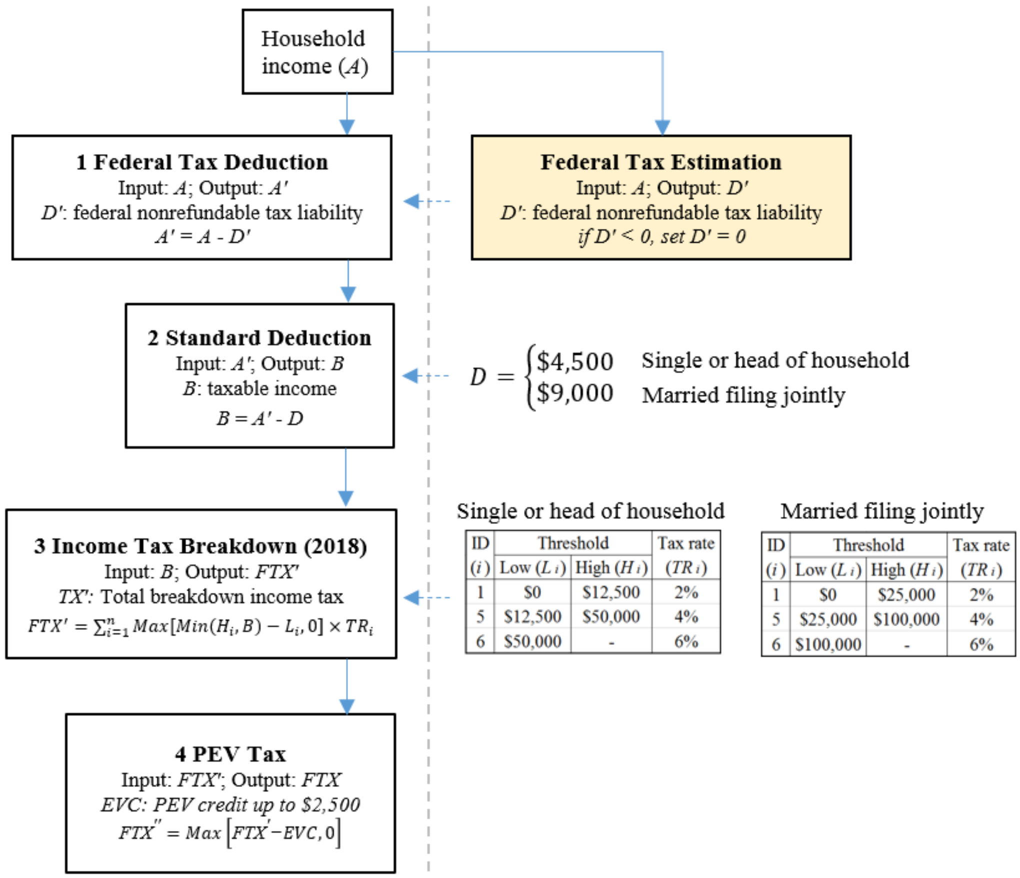


Figure 7 – Data Flow of Louisiana State Income Tax Estimation in 2018

The first example shows a married couple in Louisiana who are not eligible for the full state credit given the impact of the federal tax credit on their state tax liability:

*Example C.1: A married couple has two children and qualifies for federal child credit of $2,000 per child. The total income is **A = $70,000** in the year of 2018. They purchased a new 2018 Nissan Leaf. The federal tax liability after federal EV credit and child credit is **-$2,800 (D' = 0)**. After the standard deduction, the resulting state tax is, **FTX' = $1,940** (see step 3 in Figure 7). The family is partially eligible for PEV incentive ($1,940), and the final state tax due is, **FTX = $0**.*

*Example C.2: The same family in Example C.1 did not buy a new 2018 Nissan Leaf and so not qualified for **EVC = $2,500** tax credit. The federal tax liability is **$1,139 (D' = $1,139)**. After the standard deduction, the final state tax is, **FTX = $1,894**.*

*In conclusion, the EV credit eligibility for this family is **$1,894 - $0 = $1,894** out of $2,500. Alternatively, the family is eligible for **75.7% (1,894/2500)** of the state credit.*

The second example shows a married couple in Louisiana who are not eligible for full state credit due to the change of federal tax liability deduction

*Example D.1: A married couple has two children and qualifies for federal child credit of $2,000 per child. The total income is **A = $120,000** in the year of 2018. in the year of 2018. They purchased a new 2018 Nissan Leaf. The federal tax liability after federal EV credit and child credit is **$1,499 (D' = $1,499)**. After the standard deduction, the resulting state tax is, **FTX' = $4,070** (see step 3 in Figure 7. The family is fully eligible for PEV incentive ($2,500), and the final state tax due is, **FTX = $1,570**.*

*Example D.2: The same family in Example C.1 did not buy a new 2018 Nissan Leaf and so not qualified for **EVC = $2,500** tax credit. The federal tax liability is **$8,999 (D' = $8,999)**. After the standard deduction, the final state tax is, **FTX = $3,620**.*

*In conclusion, the EV credit eligibility for this family is **$3,620 - $1,570 = $2,050** out of $2,500. Alternatively, the family is eligible for **82% (2,050/2500)** of the state credit.*

From example D.1 and D.2, although the family's state tax liability is greater than the state credit deduction, the real eligibility is less than $2,500, because federal tax deduction increases their general state tax liability (they are paying state taxes on the federal credit). The income threshold and eligibility for Louisiana credit are summarized in Figure 8. Unlike the states in Group 1, the number of children also affects the credit eligibility through the impact of federal tax liability deduction. Unlike the federal tax eligibility in **Figure 2** showing households with higher income and fewer children are eligible for more of the federal PEV credit, high income households are not fully eligible for state credit in Louisiana, due to the impact of deductions for federal taxes paid and impact of children, which press in the opposite direction. Higher income indicates more "room" for obtaining the state credit, but this also corresponds to as much as a $7,500 decrease in their state tax deduction. The interactions are complex in Louisiana, where the "triangle areas" in Figure 8 illustrate the households that are eligible for the full $2,500 credit. In these households, the federal tax deduction equals $0 for high child credit in both "with EV" and "without EV" scenarios and the state tax credit can be fully covered by their state tax liability.

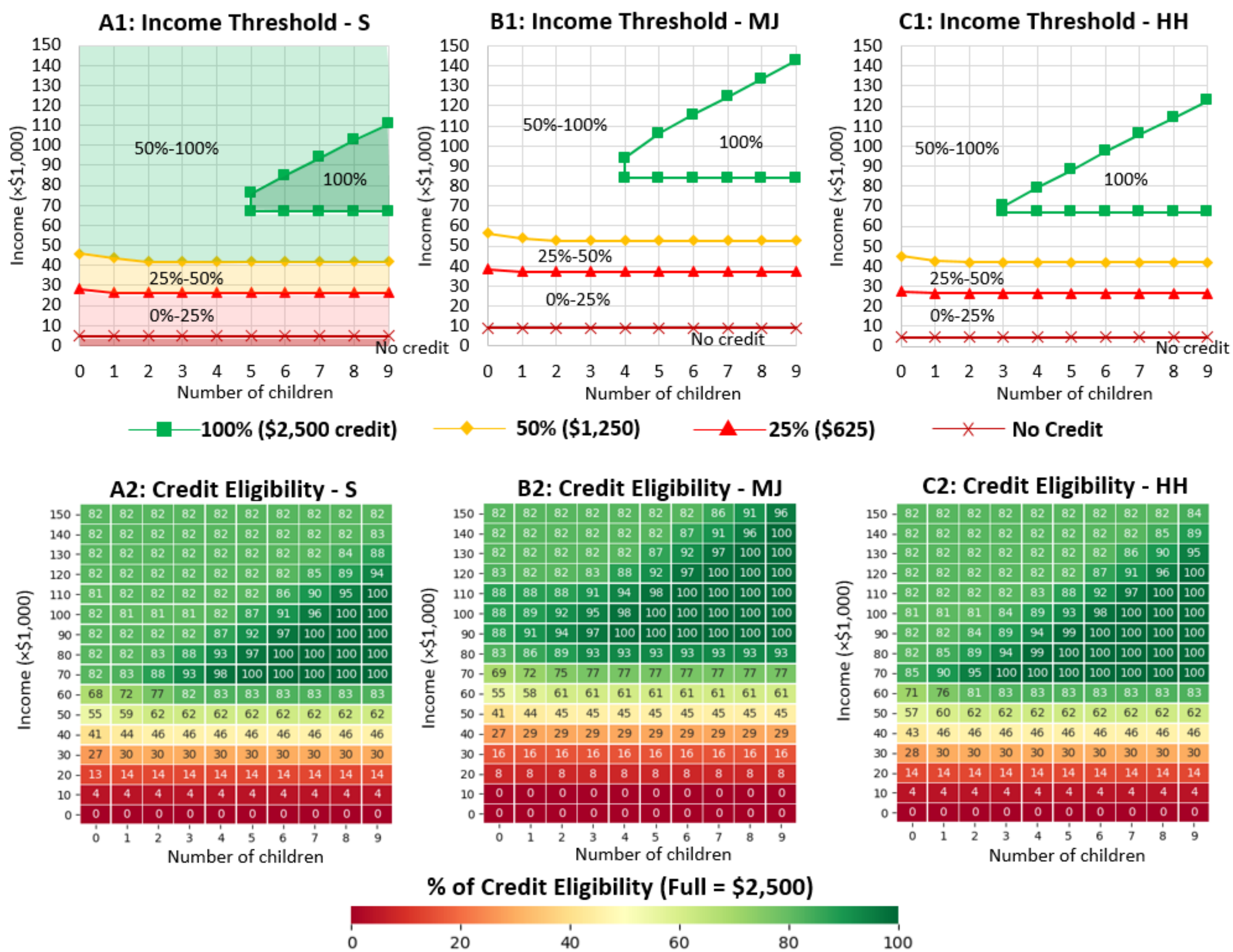


Figure 8 – Income Threshold and Eligibility for Louisiana Credit, A: Single (S), B: Married Filing Jointly (MJ), C: Head of Household (HH)

The income threshold and eligibility for Montana credit are summarized in Figure 9. It is interesting that the "balanced" credit eligibility in the upper left corner areas are -3%, which means, higher income households with few children are not eligible, or even pay a few dollars more in state tax for purchasing the EVs if they claim the federal EV credit as illustrated in the examples below.

*Example E.1: A married couple has two children and qualifies for federal child credit of $2,000 per child. The total income is **A = $120,000** in the year of 2018. They purchased a new 2018 Nissan Leaf. The federal tax liability after federal EV credit and child credit is **$1,499 (D' = $1,499)**. After the standard deduction, the resulting state tax is, **FTX' = $5,306** step 3 in Figure 7). The family is fully eligible for PEV incentive ($500), and the final state tax due is, **FTX = $4,806**.*

*Example E.2: The same family in Example E.1 did not buy a new 2018 Nissan Leaf and so not qualified for **EVC = $,500** tax credit. The federal tax liability is **$8,999 (D' = $8,999)**. After the standard deduction, the final state tax is, **FTX = $4,788**.*

*In conclusion, the EV credit eligibility for this family is **$4,788 - $4,806 = -$18** out of $500. Alternatively, the family are paying for extra **3.6% (18/500)** of the tax to state for owning an EV.*

This chapter has identified a range of potential equity issues in that benefit of EV tax credits are not equally accessible across households with different income levels and number of children. In the next chapter, the team will use individual household level demographic data to identify the population groups that are affected by the PEV eligibility in the Atlanta Metro area. The same analysis can be conducted in other states where similar demographic and vehicle use data are available.

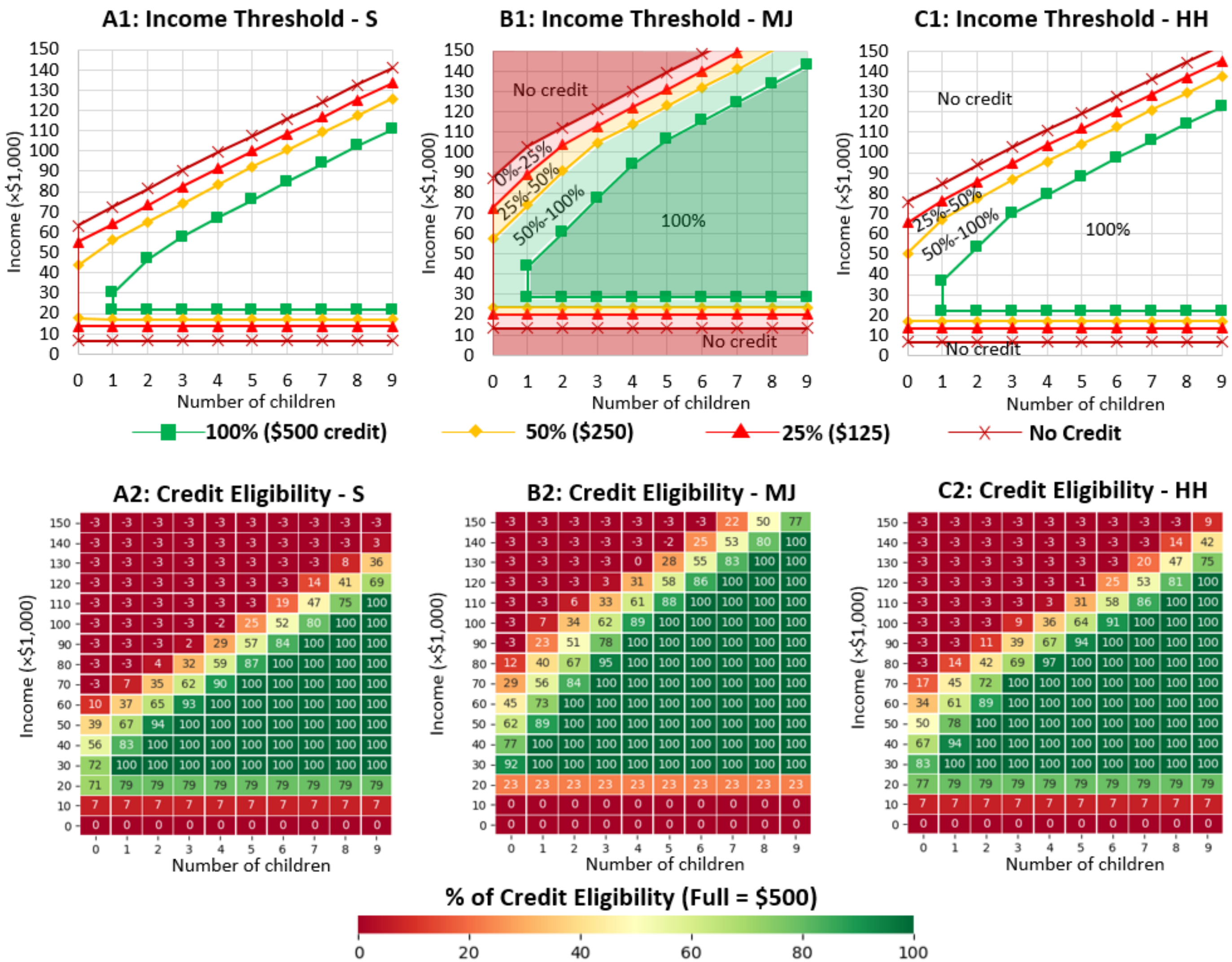


Figure 9 – Income Threshold and Eligibility for Montana Credit, A: Single (S), B: Married Filing Jointly (MJ), C: Head of Household (HH)

Chapter IV: Accessibility of PEV Incentives in Atlanta, Georgia

Chapter 3 explored credit eligibility across tax filing status, income, and number of children at the federal level and across states that provide income tax credits. The assessment across states reveals a wide range of income levels for which households do not have full access to the PEV incentives. In this chapter, the team employs household-level demographic data in the Metro Atlanta area licensed from a marketing firm, to identify the impact of PEV eligibility in the Atlanta Metro area, including the households and population that falls into each credit eligibility level. The Atlanta Metropolitan area of Georgia has a population of 5.95 million in 2018, and it is the 9th most populous metropolitan area in the United States. Most EV users in the State of Georgia are concentrated in the Atlanta Metropolitan area. Both the $7,500 Federal and $5,000 Georgia EV income tax credits have been in effect at various times in this region.

4.1. Atlanta Demographic Data

The research team has access to a licensed household demographic database from the Epsilon marketing firm that contains 2.1 million (2,125,388) household records and covers 4.47 million (4,472,575) population, updated in 2018. These data comprise around 75% of the total population in the entire Metro Atlanta region. The marketing data include such variables as household income, household marriage status, number of children and adults, head of household education level, home address, home geographic location (longitude and latitude), etc. Access to the licensed working data is restricted to project Principal Investigators, and requires a physical presence in the lab, an RFID identification to access the research zone, a second RFID identification to access the secure data center, a password-protected login to access the computers, and approved user-access to the project working directories. Appendix 1 summarized several attributes of the Atlanta demographic data used in the analysis. The spatial distribution of households and population data are presented in Figure 10.

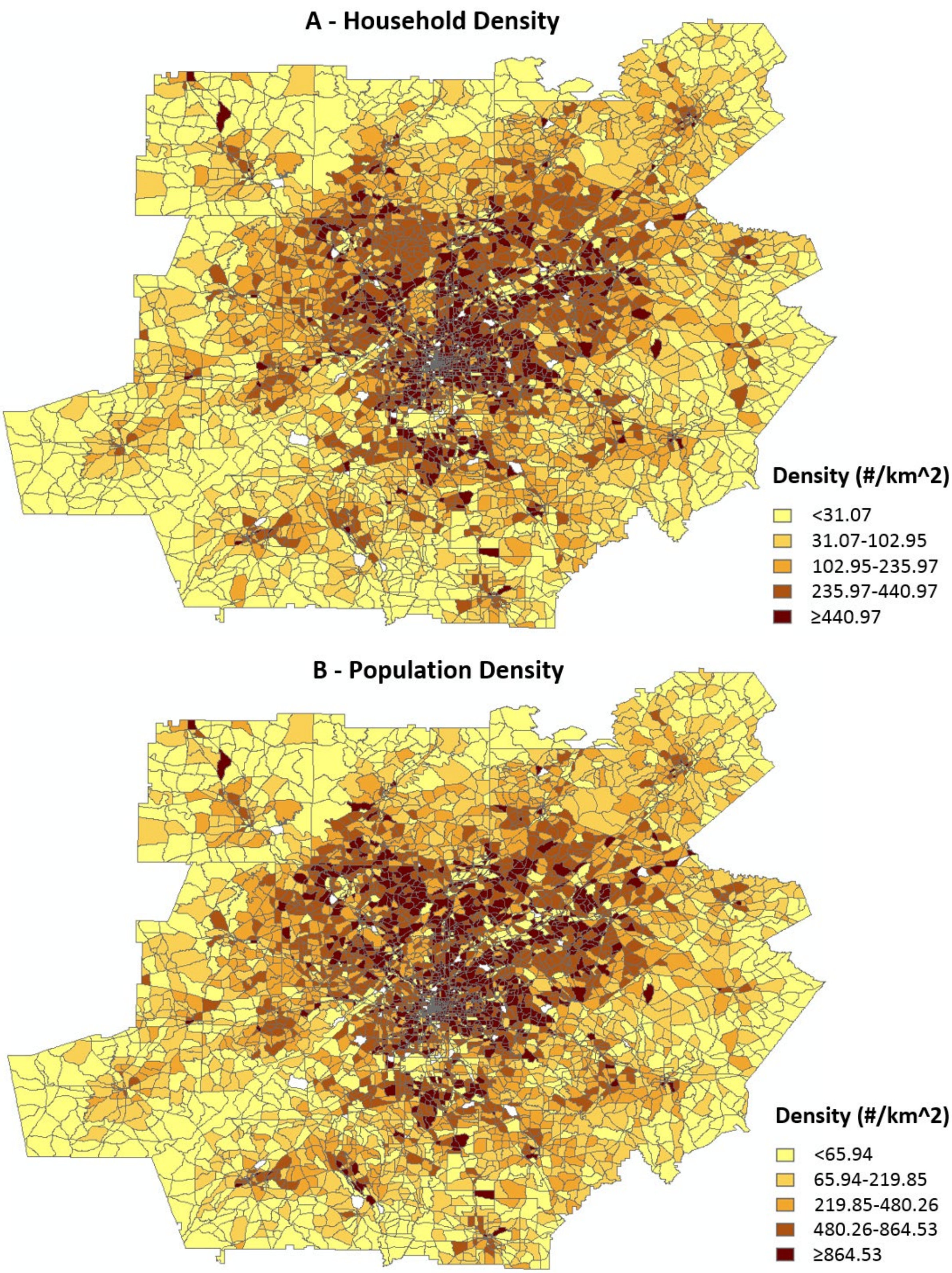


Figure 10 – Distribution of Households and Population Density (per square kilometer). A: Household, B: Population

4.2. Accessibility of PEV Purchase Incentives

The analyses that follow assume that households will choose the filing status that maximizes their total tax liability. Based on this assumption, the team estimates each household's tax filing status using the logic tree in Figure 11.

- Households with only one resident are assumed to file under the single (S) status
- Married couples are assumed to file under Married Filing Jointly (MJ) status to obtain the higher standard deduction and lower tax rates. Given that only about 5% of married couples file under the Married Filing Separately status (https://www.cbsnews.com/news/when-married-couples-should-file-separate-tax-returns/), this assumption covers most married households.

If the household has at least one child younger than 16 years old, and the primary person in the household is single, the households is assumed to file under Head of Household (HH) status, as they likely meet the filing conditions (i.e., paying for more than half of the household expenses, being considered unmarried for the tax year, and having at least one qualifying child or dependent) to obtain the higher deduction provided by this status.

- If the household has more than one resident, the head of household is not married, and there are no children, they are assumed to file as Single (S).

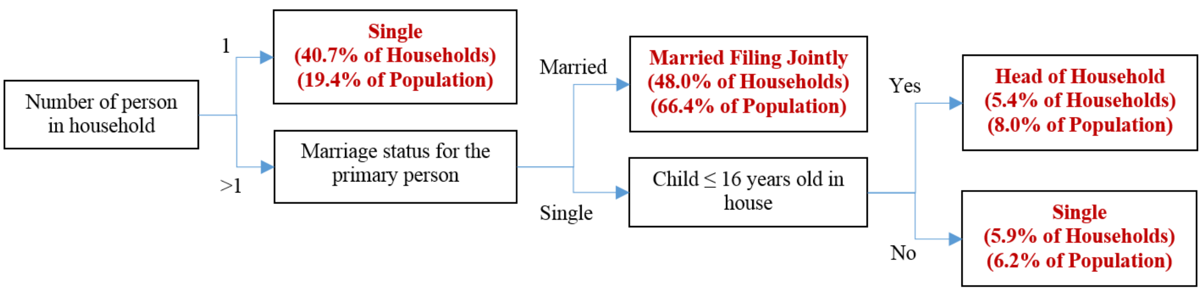


Figure 11 – Determination of Household Tax Filing Status

The PEV credit accessibility for each household income level and number of children can be estimated using the methods presented in Chapter 3. Aggregating the number of households and population by tax filing status, income level, and number of children, provides the detailed tax credit eligibility for each household demographic sub-groups, as shown in Figure 12, Figure 13 and Figure 14 below.

Households - Single (S)

Income ($)	Number of Children: 0	Total	Percent
>120K	82,293		
115-120K	8,787		
110-115K	6,337		
105-110K	4,349		
100-105K	9,861		
95-100K	32,847	331,921	33.49%
90-95K	22,874		
85-90K	22,292		
80-85K	13,403		
75-80K	24,275		
70-75K	64,244		
65-70K	40,359		
60-65K	29,965		
55-60K	25,114	162,301	16.37%
50-55K	14,213		
45-50K	93,009		
40-45K	46,073		
35-40K	21,292	170,998	17.25%
30-35K	103,633		
25-30K	24,052		
20-25K	125,535	218,261	22.02%
15-20K	68,674		
0-15K	107,693	107,693	10.87%

Population - Single (S)

Income ($)	Number of Children: 0	Total	Percent
>120K	108,885		
115-120K	11,101		
110-115K	7,754		
105-110K	5,656		
100-105K	12,139		
95-100K	40,457	408,267	35.77%
90-95K	27,603		
85-90K	26,824		
80-85K	16,437		
75-80K	29,167		
70-75K	75,487		
65-70K	46,757		
60-65K	34,689		
55-60K	30,029	187,102	16.39%
50-55K	16,726		
45-50K	105,658		
40-45K	52,977		
35-40K	24,621	192,874	16.90%
30-35K	115,276		
25-30K	27,274		
20-25K	136,646	238,268	20.87%
15-20K	74,348		
0-15K	114,977	114,977	10.07%

Credit Eligibility
100%
50%-100%
25%-50%
0%-25%
No credit

Figure 12 – Number of Households and Population for Single Filing Status (S) and Federal PEV Tax Credit Eligibility

Households - Married Filing Jointly (MJ)

Income ($)	0	1	2	3	4	5	6	7	8	9	Total	Percent
	Number of Children											
>120K	213,932	51,045	20,803	13,758	9,523	6,021	3,338	1,471	488	160	447,805	43.89%
115-120K	14,685	2,809	1,119	662	444	288	149	68	25	10		
110-115K	11,453	1,974	774	459	332	218	107	47	19	7	221,913	21.75%
105-110K	10,841	1,845	735	424	294	164	98	43	22	8		
100-105K	12,843	1,955	696	433	298	166	110	41	12	4		
95-100K	33,299	6,482	2,630	1,635	1,225	788	451	265	99	35	113,265	11.10%
90-95K	22,286	4,425	1,788	1,188	837	550	326	167	58	22		
85-90K	23,532	4,650	1,820	1,170	845	510	323	165	58	22		
80-85K	20,236	3,545	1,459	899	606	393	206	112	36	10	134,154	13.15%
75-80K	23,781	3,282	1,260	717	448	275	146	53	27	7		
70-75K	46,132	8,762	3,700	2,459	1,764	1,237	796	374	164	43		
65-70K	28,837	5,159	2,111	1,345	984	634	411	191	76	28		
60-65K	23,425	3,911	1,598	1,045	738	461	278	153	40	22		
55-60K	26,062	4,048	1,668	962	637	391	230	106	45	12		
50-55K	14,870	1,720	619	385	205	128	61	32	15	4		
45-50K	45,932	7,639	3,095	2,053	1,436	983	555	314	136	50		
40-45K	28,541	4,131	1,642	1,048	675	457	219	129	33	19	103,172	10.11%
35-40K	16,591	1,776	613	365	195	153	72	28	26	2		
30-35K	38,690	5,518	2,311	1,344	929	656	358	181	65	28		
25-30K	13,350	1,447	531	308	187	121	61	27	11	4		
20-25K	34,125	4,312	1,771	1,093	739	416	270	138	38	21		
15-20K	16,873	1,794	709	428	243	156	71	39	13	5		
0-15K	23,798	1,534	567	304	185	86	62	25	6	6		

Credit Eligibility
100%
50%-100%
25%-50%
0%-25%
No credit

Population - Married Filing Jointly (MJ)

Income ($)	0	1	2	3	4	5	6	7	8	9	Total	Percent
	Number of Children											
>120K	504,696	178,695	92,651	75,934	61,403	44,386	27,817	13,733	5,047	1,808	1,333,336	44.88%
115-120K	33,553	9,799	5,048	3,644	2,887	2,155	1,257	645	265	118		
110-115K	26,084	6,867	3,483	2,535	2,190	1,622	903	432	195	82	616,937	20.77%
105-110K	24,420	6,434	3,293	2,353	1,915	1,243	820	410	231	92		
100-105K	28,432	6,634	3,108	2,396	1,955	1,242	945	391	125	51		
95-100K	74,862	22,314	11,726	8,983	7,913	5,827	3,817	2,500	1,023	395	322,563	10.86%
90-95K	50,464	15,252	8,019	6,520	5,394	4,087	2,718	1,579	594	252		
85-90K	53,108	16,167	8,161	6,490	5,504	3,765	2,702	1,549	599	247		
80-85K	45,611	12,348	6,531	4,966	3,951	2,960	1,735	1,070	384	114	384,626	12.95%
75-80K	51,887	11,119	5,555	3,966	2,954	2,064	1,262	495	292	82		
70-75K	103,360	30,353	16,539	13,542	11,475	9,236	6,690	3,496	1,694	495		
65-70K	64,338	17,782	9,410	7,430	6,431	4,730	3,462	1,806	794	336		
60-65K	52,003	13,401	7,145	5,801	4,838	3,473	2,383	1,454	421	253		
55-60K	57,392	13,808	7,450	5,323	4,175	2,963	1,977	1,025	479	139		
50-55K	31,939	5,773	2,767	2,087	1,322	970	526	303	163	45		
45-50K	101,541	26,345	13,923	11,368	9,483	7,373	4,739	2,968	1,434	577		
40-45K	62,233	14,061	7,310	5,762	4,422	3,428	1,863	1,255	346	225	313,117	10.54%
35-40K	35,422	5,918	2,701	1,983	1,262	1,170	625	265	273	24		
30-35K	84,443	18,895	10,476	7,475	6,178	4,976	3,080	1,724	696	321		
25-30K	28,249	4,780	2,336	1,660	1,203	911	529	263	122	44		
20-25K	74,458	15,068	8,160	6,186	4,964	3,190	2,341	1,339	414	250		
15-20K	35,683	6,055	3,154	2,382	1,596	1,208	611	383	137	59		
0-15K	49,006	4,963	2,436	1,632	1,194	649	524	245	65	69		

Figure 13 – Number of Households and Population for Married Filing Jointly (MJ) and Federal PEV Tax Credit Eligibility

Households - Head of Household (HH)

Income ($) \ Number of Children	1	2	3	4	5	6	7	8	9	Total	Percent
>120K	7,228	2,065	1,099	607	318	145	44	15	5	25,353	22.26%
115-120K	704	230	117	59	31	20	4	2	0		
110-115K	483	142	70	37	20	8	5	2	1		
105-110K	420	140	80	42	27	11	3	0	2		
100-105K	772	227	104	56	25	24	8	0	1		
95-100K	2,404	593	339	172	104	43	9	4	1		
90-95K	1,600	423	212	121	67	25	18	4	1	18,945	16.63%
85-90K	1,677	431	247	123	70	45	12	12	0		
80-85K	1,165	343	173	114	62	35	7	1	1	15,856	13.92%
75-80K	1,786	481	268	152	84	38	12	3	5		
70-75K	4,176	1,081	585	316	183	86	36	6	4	18,016	15.82%
65-70K	2,902	819	390	201	112	57	22	8	2		
60-65K	2,321	604	308	188	99	49	30	11	3		
55-60K	2,235	753	351	195	101	61	25	10	0		
50-55K	1,174	364	185	111	60	20	14	2	3		
45-50K	6,126	1,633	813	473	251	120	49	16	10		
40-45K	3,778	1,133	590	326	207	100	40	13	2	35,737	31.37%
35-40K	1,845	596	277	164	86	47	21	12	2		
30-35K	7,036	1,916	916	545	283	146	50	23	10		
25-30K	2,256	692	340	192	96	48	27	5	2		
20-25K	8,089	2,073	920	499	270	135	57	13	5		
15-20K	5,163	1,383	597	344	181	100	33	13	3		
0-15K	7,639	2,133	886	478	247	115	43	16	4		

Credit Eligibility

Credit Eligibility
100%
50%-100%
25%-50%
0%-25%
No credit

Population - Head of Household (HH)

Income ($) \ Number of Children	1	2	3	4	5	6	7	8	9	Total	Percent
>120K	19,407	7,816	5,397	3,671	2,259	1,204	409	151	57	84,053	23.32%
115-120K	1,837	840	550	355	220	159	34	21	0		
110-115K	1,177	517	334	219	148	70	45	20	10		
105-110K	1,091	515	385	249	188	86	25	0	24		
100-105K	1,961	825	485	328	177	193	76	0	12		
95-100K	6,051	2,178	1,607	982	717	349	86	42	10		
90-95K	3,964	1,525	994	703	466	194	156	41	13	57,050	15.82%
85-90K	4,095	1,534	1,141	704	485	359	105	125	0		
80-85K	2,882	1,232	805	655	427	277	61	11	13	47,486	13.17%
75-80K	4,376	1,761	1,269	875	585	299	111	29	55		
70-75K	10,294	3,885	2,729	1,803	1,254	671	325	62	46	55,961	15.52%
65-70K	6,937	2,922	1,802	1,183	767	438	200	79	20		
60-65K	5,562	2,118	1,398	1,080	670	384	262	105	32		
55-60K	5,363	2,692	1,642	1,131	697	493	229	107	0		
50-55K	2,841	1,282	855	621	405	165	130	21	31		
45-50K	14,417	5,702	3,733	2,689	1,686	932	440	165	115		
40-45K	8,868	3,955	2,724	1,849	1,412	807	357	135	21	115,978	32.17%
35-40K	4,355	2,046	1,267	907	583	362	182	123	21		
30-35K	16,177	6,563	4,154	3,082	1,891	1,145	444	235	113		
25-30K	5,211	2,415	1,528	1,069	633	368	237	48	21		
20-25K	18,213	7,028	4,090	2,793	1,813	1,032	535	130	54		
15-20K	11,474	4,594	2,648	1,887	1,198	785	293	126	33		
0-15K	16,609	6,915	3,831	2,595	1,584	858	375	152	47		

Figure 14 – Number of Households and Population for Head of Household (HH) Filing Status and Federal PEV Tax Credit Eligibility

Figure 15 summarizes the proportion of credit eligibility for each of the three tax filing status categories, based on the results from Figure 12 to Figure 14. About 33.5% of single households are eligible for full $7,500 credit, and this value is significantly higher (43.9%) for MJ households, indicating higher tax liability for married families that can be used for PEV credit. In contrast, only 22.3% of HH households have access to the entire credit.

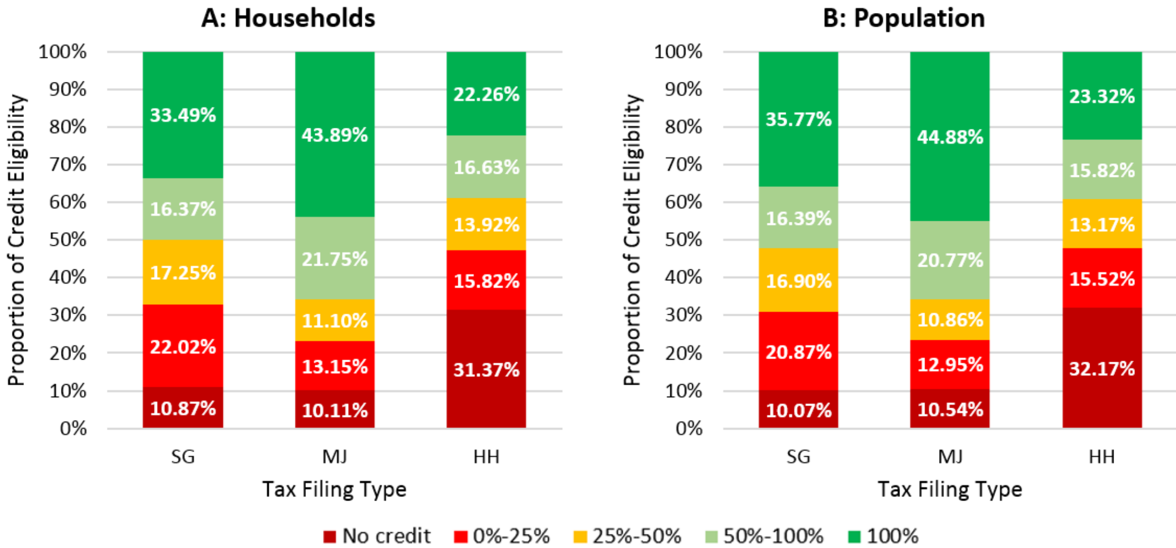


Figure 15 – Proportion of Credit Eligibility by Tax Filing Status

Figure 16 shows the cumulative proportion of households (A) and population (B) whose eligible credit is lower than the value shown on the *x* axis. The green plots highlighted in Figure 16 show that 62.1% of households (59.2% of the population) are not eligible for full federal PEV credit ($7,500). In other words, only 37.9% of the evaluated households (40.8% of population) in Atlanta are eligible for full federal credit. The orange plots indicate that 43.2% of households (39.9% of population) are only eligible for less than 50% of credit ($3,750). The red plots indicate that 29.0% of households (27.3% of population) are only eligible for less than 25% of credit ($1,875). From dark red plots in Figure 16, 11.6% of households (12.2% of population) are not eligible in any federal credit.

Figure 17 shows the similar credit eligibility information for the Georgia state $5,000 EV tax credit, which terminated on July 20th, 2015. Compared to federal credit eligibility in Figure 16, there are significantly more households and population that are eligible for full or large proportion of the $5,000 Georgia state credit – almost 80% of households (covering 85% of population) are eligible for the full state credit. This results from the state policy that the $5,000 Georgia tax credit has a maximum annual credit of $1,000 for each year of the five years following the purchase of the vehicle.

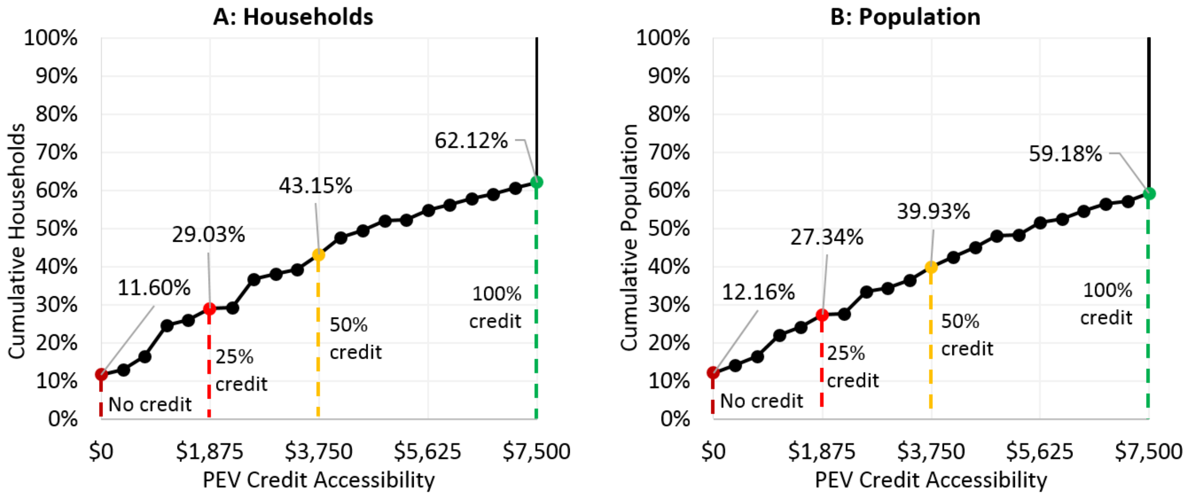


Figure 16 – Statistical Summary of Federal Credit Eligibility Level (Proportion Qualify less than X% of Credit)

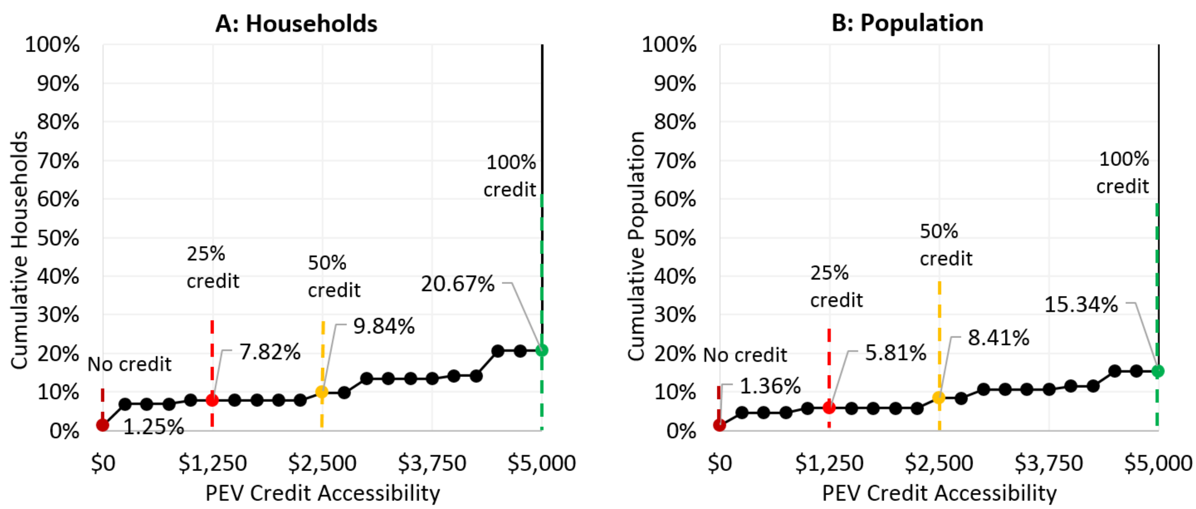


Figure 17 – Statistical Summary of Georgia Credit Eligibility Level (Proportion Qualify less than X% of Credit)

It is important to notice that, in addition to the PEV credit, the tax estimation method in this study only considers the most common credits – child credit. There are additional credits for which some households may qualify (e.g., legally blind, military service, and disabled dependent credits), and large itemized deductions to income that may apply to some households (e.g., state and local taxes, mortgage interest, extraordinary medical expenses, etc.); but we are not including these credits and deductions in this analysis. Ignoring these credits makes our credit accessibility results even more conservative. In other words, it is likely that the PEV credits are even less accessible than what it shown here, as even more households and individuals will lose their eligibility for the credit levels specified in Figure 16 and Figure 17.

Chapter V: Environmental Benefits of Adopting EVs: Vehicle Ownership and Emissions Analysis

The team has identified EV credit eligibility for each type of households across tax filing status, income level, and number of children. The analytical results reported in the previous chapter found that 62.1% of households in Atlanta are not eligible for full $7,500 federal credit, and 42.2% are not even eligible for 50% of the credit. Furthermore, the findings indicate that potential equity issues based upon the differences in EV incentive accessibility across all three factors (marriage status, income, and number of children). To assess differences in accessibility in more detail, Atlanta households will be classified into five groups for the analyses that follow, based on their Federal EV credit eligibility level: households that can capture 100% of the incentive, 50%-100%, 25%-50%, 0-25%, and households that can capture "no credit" for purchase/lease of a BEV.

In this chapter, the research team uses license plate data collected in the field and matched with demographic information to compare the air pollutant and greenhouse gases (GHGs) emissions rates across household groups as an indication of potential environmental benefits experienced from replacing existing conventional vehicles with battery electric vehicles.

5.1. License Plate Data Collection and Vehicles Matching

The research obtained vehicle fleets of Atlanta households that are actively operated on roads by collecting on-road license plate data, and matching with vehicle registration and Atlanta demographic data. Funded by the State Road and Toll Authority (SRTA) project, a comprehensive vehicle license plate data collection has been conducted in the Metro Atlanta area in Fall 2018, Spring 2019, and Fall 2019 to assess the impacts of Georgia's Express lanes on vehicle and person throughput. Three sites in I-75/I-575 North Corridor, three sites in I-85 North Corridor, one site in I-75/I-85 at Atlanta Midtown, and one site in I-75 South Corridor were selected for data collection as they provided good data collection views, a good spatial distribution of coverage, and provided safe access and observation points (e.g., protected by guardrails, access via crosswalks and signals, etc.). The sites on I-75/I-575 Northwest Corridor include I-575 at Chastain Road (Exit 3); I-75 Express Lane Ramps at Hickory Grove Road; and I-75 Express Lane ramps at Roswell Road. The sites on the I-85 North Corridor include I-85 at Indian Trail/Lilburn Road (Exit 101); I-85 at Old Peachtree Road (Exit 109), and I-85 at Hamilton Mill Road (Exit 120). The I-75/I-85 Midtown site was I-75 at Tenth Street (Exit 250). The I-75 South Metro site was I-75 at Jodeco Road (Exit 222).

Traffic inbound to Atlanta was monitored during the morning peak periods (usually 7AM-10AM) and in the outbound direction in the afternoon peak periods (usually 3:30PM-6:30PM). Hence, the team monitored morning traffic in the southbound direction on the I-75/I-575 Northwest corridor and I-85, and in the northbound direction on the I-75 South Metro corridor. The team monitored afternoon traffic in the northbound direction on the I-75/I-575 Northwest corridor and I-85, and in the southbound direction on the I-75 South Metro corridor. Videos from five days were collected from each site. Figure 18 shows the license plate video collection sites at these corridors.

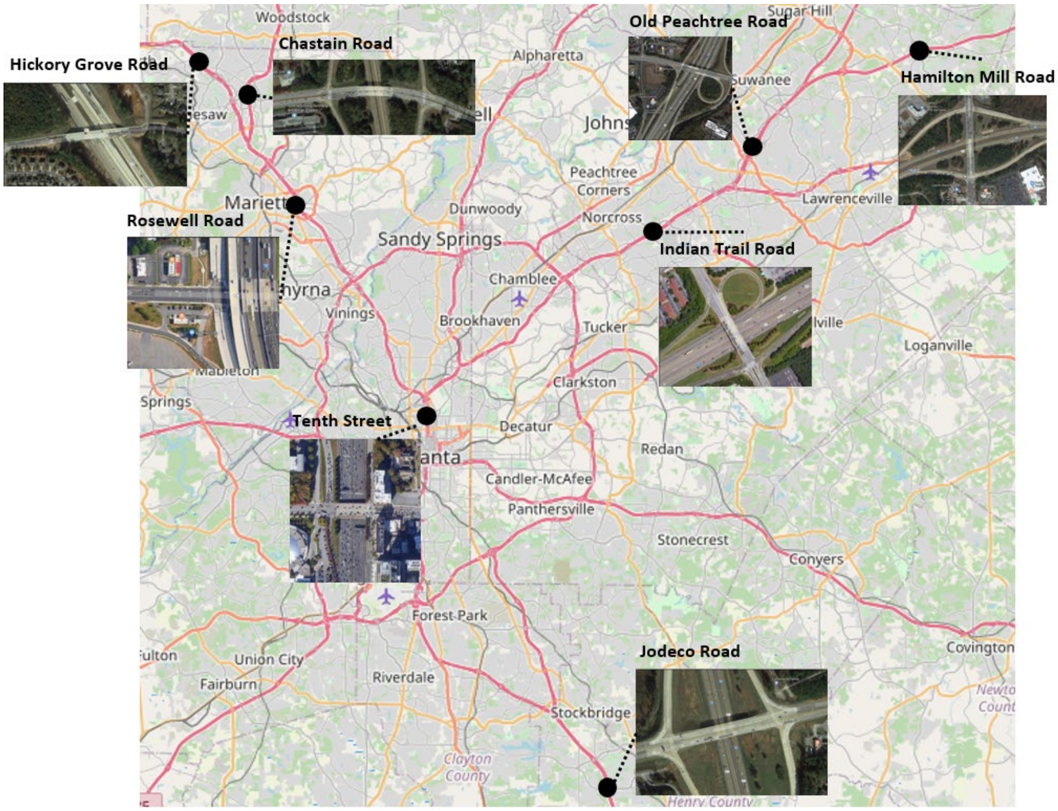


Figure 18 – License Plate Video Collection Locations

License plate information are extracted through an automatic vehicle detection, image extraction and license plate recognition system developed by the research team. A 50-layer Region-based Convolutional Neural Network (R-CNN) was pre-trained based on COCO motor vehicles dataset to recognize vehicle image from the video image. License plate characters are then automatically extracted using an Optical Character Recognition (OCR) algorithm. Given a video of general purpose lane or managed lane, the system is able to output one image for each vehicle and the corresponding data (vehicle type, license plate number, time of appearance, lane number, etc.), as shown in Figure 19.

Figure 19 – Automatic System for Vehicle and License Plate Capture

In total, the team has captured 540,964 unique plates (in total of 1,122,002 plates records, including repeated records due to the multiple-time capture) for this research. License plate records are first processed to obtain vehicle make, model, model year, and fuel type for energy and emissions analyses. In a single-blind process, the team pairs each license plate with licensed demographic data. The plate-demographics pairs returned from this process allow the team to integrate demographic data into the energy and emissions analyses for the observed vehicles, without carrying physical address and vehicle ownership information into the analyses. Observed plates are also assigned to their corresponding transportation analysis zone in the regional travel demand model, so that generalized spatial plots can be prepared. The demographic data set for 2.1 million households in the Metro Atlanta area was licensed from Epsilon and contains data for income, number of children, marriage status, etc., allowing the team to perform analyses of Atlanta households that will match the previous incentive accessibility analyses conducted in Chapter 3 and Chapter 4

The total number of plates captured and matched with vehicle and demographic information are summarized in Table 4. It is important to note that the sampled households from license plate collection and matching process do not provide an unbiased representation of the Atlanta demographics. This process automatically filters out the households who do not own a vehicle, or who do not use vehicles during commute period, both of which are associated with lower income families.

Table 4 – Number of Plates Captured and Matched

Site	Number of Unique Plates Captured	Plates Matched with Vehicle Data	Plates Matched with Vehicle and Demographic Data
Tenth Street	110,454	88,815 (80.4%)	63,394 (57.4%)
Chastain Road	67,275	53,002 (78.8%)	38,871 (57.8%)
Hickory Grove Road	67,257	47,470 (70.6%)	12,787 (19%)
Hamilton Mill Road	39,322	21,283 (54.1%)	31,320 (79.7%)
Indian Trail Road	135,703	107,004 (78.9%)	79,055 (58.3%)
Jodeco Road	31,328	26390 (84.2%)	15196 (48.5%)
Old Peachtree Road	84,305	63399 (75.2%)	44074 (52.3%)
Roswell Road	4,292	3527 (82.2%)	2856 (66.5%)
Total (Match Rate)	539,936	410890 (76.1%)	287553 (53.3%)

5.2. Vehicle Distribution Analysis

Many factors affect vehicle emissions, including vehicle class, vehicle weight, vehicle age, fuel type, on-road operating conditions, temperature, humidity, etc. Of all of the factors that affect energy use and emissions, vehicle class (larger SUVs) and vehicle age are directly correlated with household income (EIA, 2020; Khoeini and Guensler, 2014). In general, older vehicles tend to have higher emissions because they use less sophisticated on-board computers and emissions control technologies than newer vehicles, were designed to meet less stringent emission standards at the time they were manufactured (depending on the model year), and their emissions control systems (primarily system sensors and actuators) tend to deteriorate over time.

Using 2019 as the scenario year, Figure 20 presents the average vehicle age per household for their tax filing status, income level, and number of children, color coded from green (younger vehicles) to red (older vehicles). Despite the noise in the data, it is not hard to see from the license plate data analysis that households with lower income tend to own older vehicles. Analyses in the previous chapters found that lower income households face greater barriers to obtaining credits when purchasing EVs; however, the age distribution of the fleet in the figures indicates that replacing older vehicles in these lower income households with EVs might yield larger energy reduction and environmental benefits (if annual mileage accrual rates are comparable across incomes). This will be further quantified in the next section.

Based on the license plate data, the team also compared the federal credit eligibility of conventional gasoline owners (201,708 households owned only conventional vehicles) with the eligibility of current BEV owners (1,199 households owned one or more BEVs), as shown in Figure 21. Of the households that own only conventional vehicles, for which vehicles were observed based upon license plate data collection, 49.4% are eligible for the full value of the federal credit. This proportion is higher than the 37.9% of Atlanta Metro area households eligible for the full credit from the regional demographic database presented earlier (Figure 16). This is not surprising because the vehicles observed on the freeways during peak commute period represent higher income households than the regional Atlanta average. The bar chart in the right side of Figure 21 shows that the vast majority (83.1%) of households that own BEVs are eligible for full $7,500 credit, which is much higher than that of the Atlanta average or that of the households that own no BEVs. Even if we assume that the marketing database used to infer income has a significant amount of uncertainty at the household level, the difference is quite large. The results indicate a large difference in the household incomes of BEV owners and non-BEV owners. The results may also indicate that households that purchased EVs did their homework and knew that they would qualify for incentives. Figure 21 does not necessarily infer that higher income households were more willing to purchase BEVs because of the credit. Early adopters may place a higher value on new technology and the environment, which may drive purchase behavior more than the incentive itself. However, when the $5,000 State of Georgia credit was eliminated in 2015, the sales of BEVs plummeted in Atlanta, indicating that the incentives were a major factor in purchase decisions.

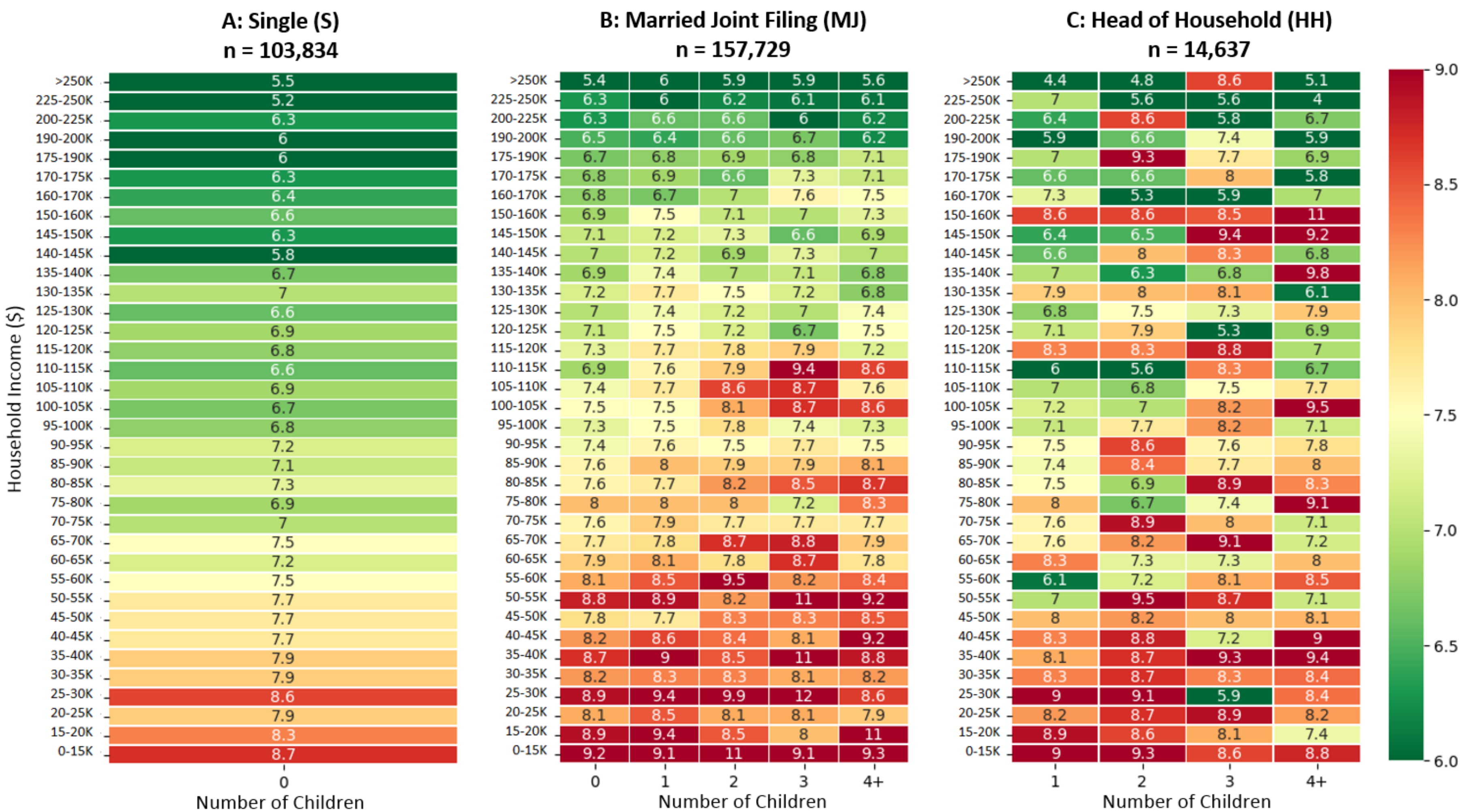


Figure 20 – Mean Vehicle Age (in 2019) by Household Tax Type, Income, and Number of Children

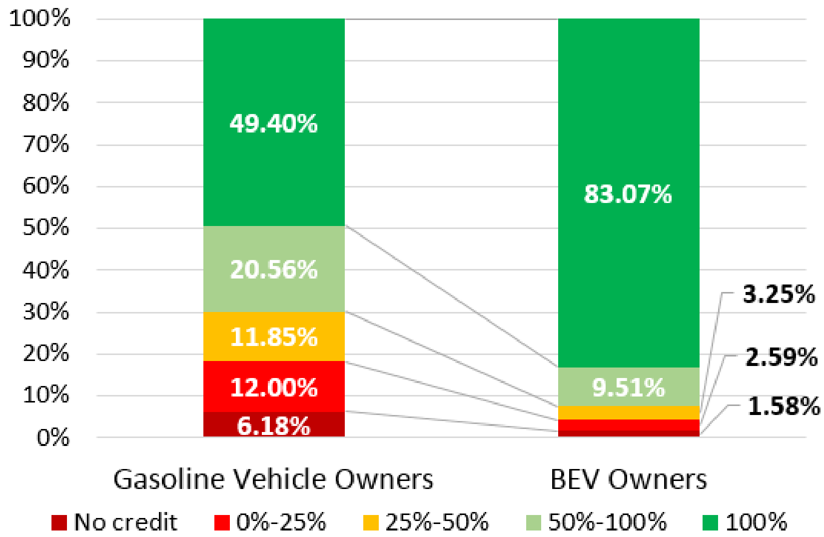


Figure 21 – Credit Eligibility of Conventional Gasoline Owners (201,708 Households Captured) vs. BEV Owners (1,199 Households Captured)

5.3. Emissions Analysis

As noted earlier, lower income households tend to own older vehicles, which generally corresponds to higher emissions rates. Hence, the potential environmental benefits for adopting BEVs may be greater in lower income commuting households than higher income commuting households (depending also on annual mileage accrual across these households). To assess the potential energy savings and emission benefits, the team will compare emissions rates (grams per mile per vehicle) of households across tax credit eligibility groups, including tailpipe pollutant emissions for carbon monoxide (CO), oxides of nitrogen (NOx), volatile organic compounds (VOCs), and fine particulate matter ($PM_{2.5}$), and fuel-cycle greenhouse gas emissions (GHGs). In this study, GHGs emissions is quantified as carbon dioxide (CO_2) equivalent, a standard unit of measuring carbon footprints that convert the various GHGs (CO_2, CH_4 and N_2O) into equivalent amounts of CO_2, based on their global warming potential (GWP) describing the warming impact relative to CO_2 over one hundred years (EPA, 2020). Emissions from fuel cycle GHGs process (or "well-to-wheels" process) are estimated to support a "fair" comparison of environmental impact across different travel modes, which consists of on-road tailpipe GHGs emissions and fuel production emissions.

On-road tailpipe emissions are estimated using MOVES-Matrix. The MOtor Vehicle Emission Simulator (MOVES) is an emission modeling system released by the US Environmental Protection Agency (USEPA) to estimate emission rates for mobile sources in the United States (USEPA, 2015a). States are required to use the MOVES model for State Implementation Plan (SIP) development or conformity analysis (Vallamsundar and Lin, 2012; USEPA, 2015b). The MOVES model employs a "binning" approach to modeling and estimate emissions as a function of Vehicle Specific Power (VSP) and operating speed (USEPA, 2015a). MOVES-Matrix is composed of the outputs from a tremendous number of MOVES model runs Liu et al., 2019). The process is constructed to run MOVES across all variables that affect output emission rates and obtain emission rates for all pollutant types from all vehicle source types, model years, on-road operating conditions under a wide range of calendar years, fuel properties, inspection and maintenance (I/M) program characteristics, and meteorology conditions (Guensler, et al., 2016). After conducting hundreds of thousands of MOVES runs, the resulting MOVES emission rate matrix (MOVES-Matrix) can be queried to obtain the exact same emission rates that would be obtained for any MOVES model run, without ever having to launch MOVES again. Hence, MOVES-Matrix emission rates can be integrated into emission modeling work from the development of regional scale inventories, to assessment of corridor emissions and energy use for monitored vehicle fleet activity, to microscale dispersion analysis for air quality impact assessment (Xu et al., 2016; Xu et al., 2017; Liu et al., 2017; Liu et al., 2019).

The emission database in MOVES-Matrix was grouped into multiple sub-matrices, with each sub-matrix storing emission rates for all vehicle source types, all source model years, all on-road operations, for one specific region (Atlanta is used in this study), calendar year (2019 in this study), month, temperature, relative humidity, fuel supply (determined by region, year and month), and I/M strategy (determined by region and year). This way, a small subset of emission rates can be extracted from the matrix based on the user's year, month, and meteorology inputs. This structure helps support analyses for any emission control strategies, given that users generally pay attention to a single temperature, humidity, and fuel condition, when exploring the impacts of strategies on traffic activity and emissions. After the sub-matrix of emission rates is identified and accessed, the emission rate processing is the same as used by MOVES in project-level modeling. MOVES-Matrix weights the emission rates from individual source types to generate the composite emission rate. The weighting combines on-road vehicle activity, as defined by the combined source type and model year distribution (newer vehicles typically account for a larger share of the on-road fleet activities than older vehicles) and the amount of on-road vehicle activity in each operating mode bin to calculate a composite emission rate for each link. Emissions from fuel production process are estimated using "well-to-pump" module of GREET model. GREET is designed to evaluate energy and emission impacts of vehicle technologies and transportation fuels, the fuel cycle from wells to wheels and the vehicle cycle through material recovery (ARNL, 2020).

For on-road tailpipe emissions rates modeling, the two main input sets are vehicle and operating information. Vehicle make, model, model year (an indication of emission standards, vehicle technology, and deterioration rates), and fuel type are available in this study, and matched with the EPA engine certification database to obtain EPA regulatory class and MOVES source type, or vehicle class (USEPA, 2019). For example, 2012 Ford Fusion is classified as 2012 gasoline passenger car (source type 21) in MOVES vehicle category; 2013 Ford Edge is classified as 2013 gasoline passenger truck (source type 31). More details on the vehicle class matching process can be found in Liu, et al., (2015). The "driving cycle" method in MOVES-Matrix project-level analysis is applied to obtain energy use and emission rates for each vehicle. In this study, vehicle emission rates are estimated by applying FTP-75 (Federal Test Procedures) in MOVES-Matrix, a standard driving cycle that has been used for emission certification and fuel economy testing of light-duty vehicles in the United States. The second-by-second driving schedule of FTP-15 cycle is shown in Figure 22. Of course, if more detailed driving cycle data were available for these on-road fleets, such as from monitoring of household vehicle travel (i.e., instrumented vehicle data), the monitored on-road activity data could be used with the methods described here.

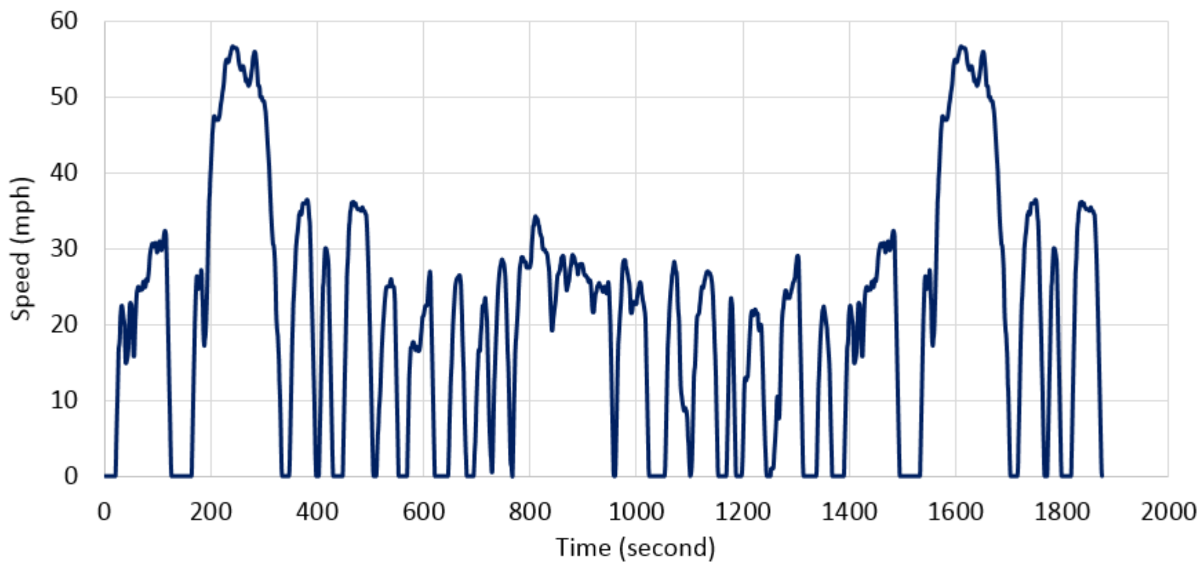


Figure 22 – The US EPA Urban Dynamometer Driving Schedule (FTP-75)

Given the driving cycle, Vehicle Specific Power (VSP) is calculated first to represent second-by-second engine loads using the equation below.

$$VSP_t = \left(\frac{A}{M}\right) v_t + \left(\frac{B}{M}\right) {v_t}^2 + \left(\frac{C}{M}\right) {v_t}^3 + \left(\frac{m}{M}\right)(a_t + g * \sin\theta_t)v_t \qquad (1)$$

Where:

v_t = velocity at time t (m/sec)
a_t = acceleration at time t (m/sec^2)
θ_t = road grade as the ratio between vertical movement to horizontal distance (%)
g = graviational acceleration (9.81 m/sec^2)
m = vehicle mass (tonnes)
M = fixed mass factor for the source type (tonnes)
A = rolling resistance (kW − sec/m)
B = rotating resistance (kW − sec^2/m^2)
C = aeodynamic drag (kW − sec^3/m^3)
M = fixed mass factor (tonnes)

With speed and VSP values available for each second of operating data, MOVES-Matrix then assigns each second of activity to its appropriate operating mode bin, as shown in Appendix 3, and assigns the corresponding emission rates. Next, energy use output (along with fuel type) from MOVES model serves as the input for GREET model, the 2017 U.S. national default refinery process for gasoline and diesel production are chosen to estimate the GHGs emissions for producing such amount of fuel supply, indicating 0.0232 grams of GHGs (CO_2 equivalent) per kilojoule of gasoline production, and 0.0168 grams per kilojoule of diesel production.

The normalized emissions rates for gasoline passenger cars from model year 1988 to 2019 are shown in Figure 23 based on MOVES-Matrix results. Tailpipe emissions of all the criteria pollutants have declined dramatically since 1990 when the Clean Air Act (CAA) was amended and Tier 1 emission standard were adopted. With the further implementation of Tier 2 and Tier 3 standards over the last 20 years, on-road pollutant emissions of new vehicle in 2019 have decreased by more than 90%. In contrast, GHGs emission rates remained the same until 2012, when stricter CAFE standard went into effect under the Obama Administration.

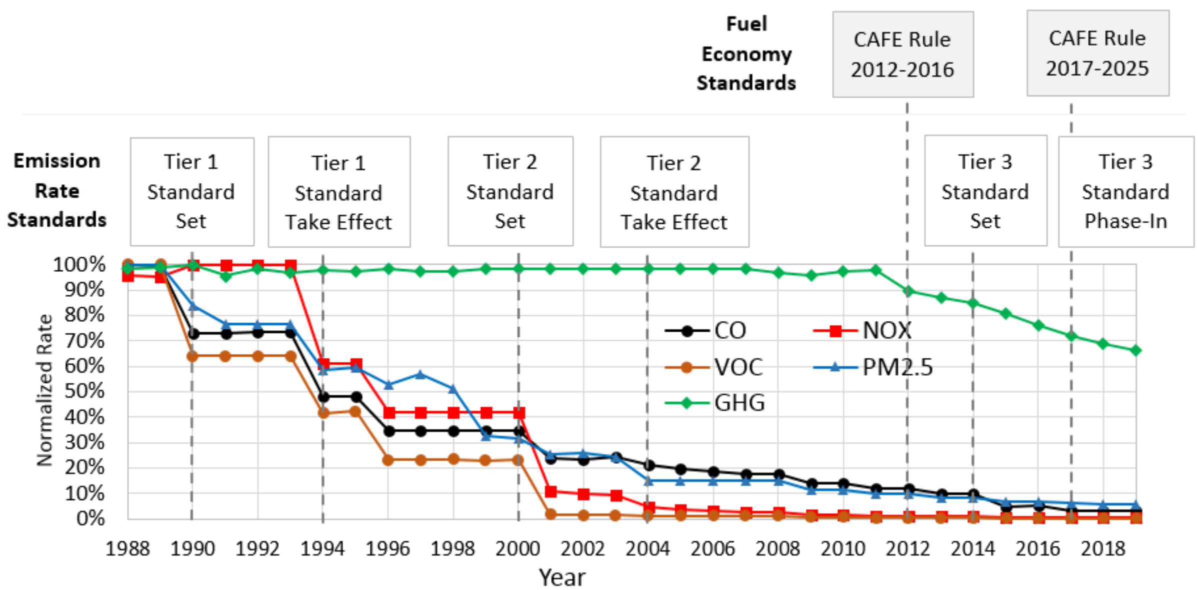
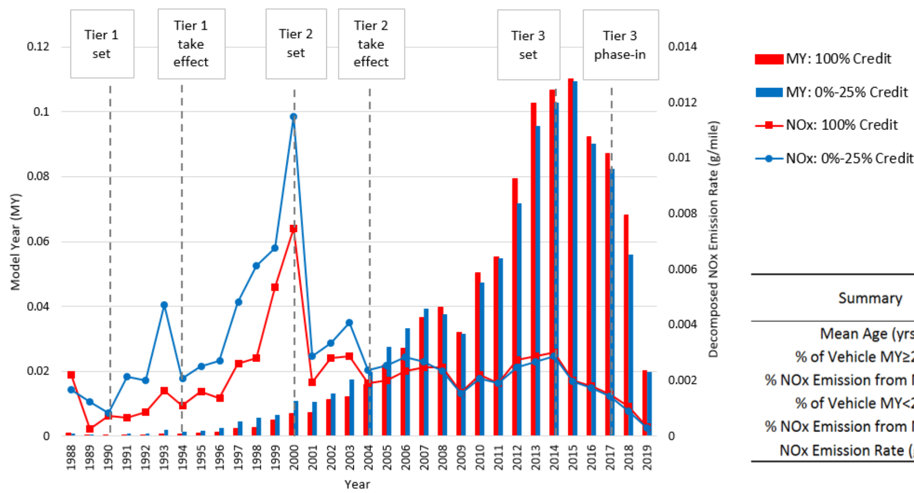


Figure 23 – Normalized Emission Rate for Gasoline Passenger Cars in Response to Emissions and Fuel Economy Standards

Figure 24 shows the emission contributions by vehicle model year from the observed households that are eligible for 100% of the fedral credit vs. 0-25% of the federal credit. In this analysis, we assume that each vehicle observed on the freeway is conducting an equivalent trip (i.e., travels the same number of miles for the observed trip). Because gram/mile emission rates for older vehicles are so much higher than the emission reates for newer vehicles, as much as a factor of ten, a small number of these vehicles on a corridor contribute dosproportionately to corridor emissions. Multiplying the emission rate for each vehicle model year by the observed on-road vehicle distribution for that model year from the license plate collection, we find that the small proportion of "older" vehicles contributes to the majority of criteria pollutants. For example, in "100% credit" households, only 5.4% of vehicles are older than model year 2014 (i.e., before Tier 2 standard took effect), but these vehicles contribute 53% of NOx emissions. Also, the fleet for "0%-25% credit" household averages 5.67 years old, or 0.56 years older than fleet from "100% credit" households. This seemingly small difference in average age results in a large difference in emission levels between these two fleets. The average NOx emission rate for the "0%-25% credit" household fleet of 0.092 grams per vehicle per mile is 33% higher than the average NOx emission rate for the "100% credit" household fleet of 0.069 grams per vehicle per mile. This along with Figure 20, which presents average vehicle age across households demographics, demonstrate the large difference in emission rates for these vehicles across household income levels. The corresponding emission rates for each detailed household type are calculated and shown in Appendix 4.



Summary	Households	
	100% Credit	0%-25% Credit
Mean Age (yrs)	5.67	6.23
% of Vehicle MY≥2014	94.6	92.0
% NOx Emission from MY≥2014	47.0	35.5
% of Vehicle MY<2014	5.4	8.0
% NOx Emission from MY<2014	53.0	64.5
NOx Emission Rate (g/mile)	0.069	0.092

Figure 24 – Emission Contribution by Model Year: Fleet of Households Eligible for 100% Credit vs. 0-25% Credit

Figure 25 and **Figure 26** show the average emission rates (grams per vehicle per mile) of the passenger cars and passenger trucks by households credit eligibility group. The emission comparison results are also summarized in Table 5. Vehicles from households with lower income levels produce higher emissions and would provide greater emission reduction benefits and energy savings if they were replaced with BEVs, assuming that daily vehicle use is comparable. However, these households are less likely to qualify for the full federal or state tax incentive.

Table 5 – Percentage Emission Increase
Compared to Vehicles from Households with 100% Eligible Credit

Passenger Cars					
Credit Eligibility	**CO**	**NO_X**	**VOC**	**GHG**	**$PM_{2.5}$**
No credit	+12.61%	+54.79%	+67.06%	+1.23%	+13.74%
0%-25%	+8.31%	+34.36%	+41.14%	+0.87%	+9.23%
25%-50%	+6.60%	+22.20%	+23.69%	+0.81%	+6.98%
50%-100%	+6.29%	+21.40%	+26.78%	+0.78%	+6.39%
Passenger Trucks					
Passenger Truck	**CO**	**NO_X**	**VOC**	**GHG**	**$PM_{2.5}$**
No credit	+48.64%	+98.64%	+143.99%	+6.41%	+33.34%
0%-25%	+36.35%	+76.25%	+105.22%	+4.89%	+26.00%
25%-50%	+30.25%	+60.19%	+81.88%	+4.24%	+21.67%
50%-100%	+19.27%	+39.15%	+55.96%	+2.70%	+13.48%

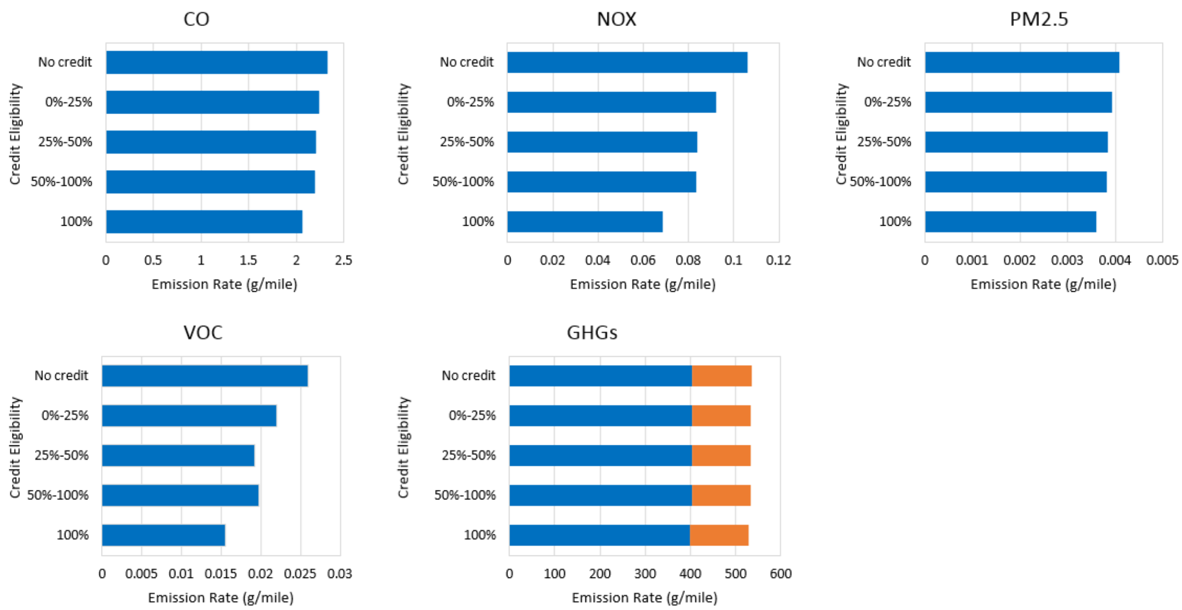


Figure 25 – Passenger Car Emission Rates of Household Vehicles by Credit Eligibility
(Blue as Tailpipe Emissions, Orange as Fuel Upstream Emissions)

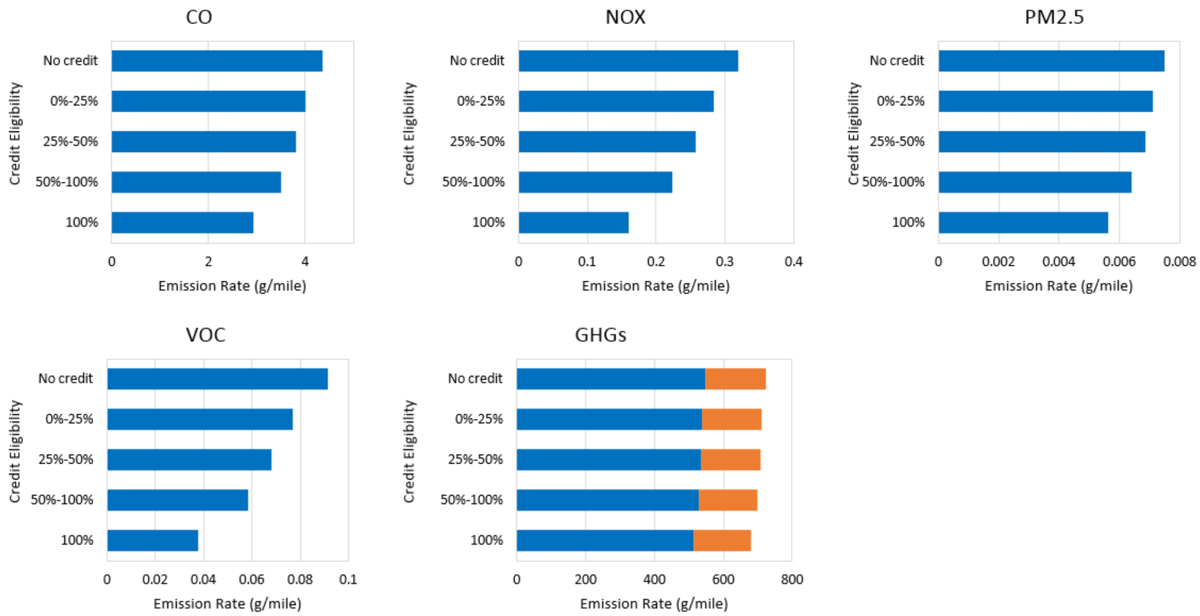


Figure 26 – Passenger Truck Emission Rates of Household Vehicles by Credit Eligibility (Blue as Tailpipe Emissions, Orange as Fuel Upstream Emissions)

Chapter VI: Distributive Justice

The concept of distributive justice is a fundamental part of environmental ethics. From a practical perspective, distributive justice is the assessment of whether an allocation of costs and benefits associated with a policy is fair or equitable. Each individual's assessment of distributive justice can only be performed in light of each individual's application of their individual concept of moral standing, which focuses on who's interests count and why. In distributive justice, individuals assess how much the interests of each individual or group should count. That is, what is the fair and equitable distribution of costs or benefits of a policy across individuals or groups that have moral standing. Individuals are fundamentally deciding whether the distribution of "who benefits," "who pays," and "how much" is fair. Any individual's assessment as to whether resource distributions are equitable is predicated upon each individual set of core philosophical constructs which differs significantly across individuals with respect to metaethics, core values, instrumental values, epistemology, concepts of moral standing, systems of distributive justice, normative ethics, etc. Hence, policy analysis generally focuses on identifying the differences in policy outcomes across a wide variety of interest groups that may have distributional claims, and allowing the political system to develop the compromises necessary to achieve successful policy implementation and maintenance over time. Within the framework outlined above, Environmental justice is a subset of the larger universe of distributive justice.

The Environmental Justice movement began in 1968 with the Memphis Sanitation strike, started primarily to address inequities in community environmental protection. Title VI of the Civil Rights Act of 1964 had already prohibited discrimination based on race, color, or national origin in programs or activities which receive federal financial assistance. However, it was painfully clear that black and low income communities were facing significantly greater environmental health hazards than white and affluent communities. The USEPA's History of the Environmental Justice Movement slide deck (https://www.epa.gov/environmentaljustice) outlines decades of progress made in this field.

The U.S. Environmental Protection Agency now defines environmental justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. The USEPA defines the metrics for success as being met when all communities and persons enjoy: 1) equal protection from environmental and health hazards, 2) equal access to the decision-making process, and 3) a healthy environment in which to live, learn, and work. Similarly, Executive Order 12898 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations) signed by President Clinton in 1994 focuses federal attention on the environmental and human health conditions of minority and low-income populations with the goal of achieving environmental protection for all communities. Executive Order 12898 states that agencies "…shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States and its territories and possessions…." Hence, the working definition of environmental justice (thus, distributive justice) in environmental policy implementation does not focus on equal or comparable distributional benefits, but on equal protection from hazards and assurance that low-income and minority populations will not face disproportionately high and adverse human health or environmental effects.

BEV Incentives and Distributive Justice by Income

Table 6 presents the eligibility for the $7,500 federal tax incentive, based upon the Epsilon demographic database, wherein about 61.8% of metro area households earn $75k/year or less, 14.0% earn between $50k and $75k/year, and 24.2% of households earn $100k or more per year. With respect to income, none of the households earning less than $50k/year, and only 27% of the households earning between $50k/year and $75k per year would qualify to receive the entire federal tax credit. About 11.7% of metro area households are not eligible to receive any credit at all, and about 29.1% are eligible to receive less than 25% of the credit; the vast majority of these households earn less than $50k/year. Whereas, more than 99.5% of the households earning more than $100k/year (24.1% of all metro area households) qualify for the entire federal tax credit. The income disparity with respect to qualification for federal tax incentives benefits is significant and striking. Higher income households qualify for the majority of the credits. Further exacerbating this issue is the fact noted earlier that households with children are eligible to receive a lower percentage of these credits. With respect to the Environmental Justice in public policy, however, there are no significant negative environmental consequences associated with the distribution of the incentives across households. Hence, under the Executive Order on environmental justice, there is no disproportional negative impact on lower income groups to be addressed.

With respect to the $5000 Georgia Tax credit, which is spread over a five-year deduction period, and which is not reduced by taking child tax credits, a significantly percentage of lower income Georgia households qualified for the state tax credit than for the federal tax credit. Table 7 presents the eligibility for Georgia state tax incentives based upon the Epsilon demographic database, again where about 61.8% of metro area households earn $75k/year or less, 14.0% earn between $50k and $75k/year, and 24.2% of households earn $100k or more per year. With respect to income, 100% of the households earning more than $25k/year qualify to receive the entire Georgia tax credit. Only about 1.3% of metro area households were not eligible to receive any credit at all, and only about 6.6% were eligible to receive less than 25% of the credit (all of these households earned less than $20k/year. Whereas, 100% of the households earning more than $50k/year and 79.3 percent of all households in the metro area qualified for the entire state tax credit. The income disparity with respect to qualification for, and potential receipt of Georgia tax incentives benefits is much, much lower than for the federal tax credit. In fact, the Georgia tax credit was much more egalitarian across income than the federal tax credit. With respect to the Environmental Justice in public policy, as noted previously, there are no significant negative environmental consequences associated with the distribution of incentives and no disproportional negative impact on lower income groups to address. However, given the fact that the Georgia incentives were more accessible to lower income households, it seems that revisiting the structure of the federal incentive policy would be worthwhile, perhaps aligning the Federal program structure with that of Georgia.

Table 6 – Federal Incentive Eligibility by Household Income

Income	% HH	% of Households Observed by Federal Credit Eligibility				
		No Credit	0% to <25% of Credit	25% to <50% of Credit	50% to <100% of Credit	100% of Credit
<$20k	11.5%	71.7%	28.3%	0.0%	0.0%	0.0%
$20-$50k	32.3%	10.5%	42.7%	33.3%	13.5%	0.0%
$50-$75k	18.0%	0.1%	2.2%	18.0%	52.4%	27.3%
$75-$100k	14.0%	0.0%	0.1%	0.8%	36.2%	62.9%
$100-$150k	14.4%	0.0%	0.0%	0.0%	0.5%	99.5%
$150k+	9.8%	0.0%	0.0%	0.0%	0.0%	100.0%
Income	% HH	% of Population Observed by Federal Credit Eligibility				
		No Credit	0% to <25% of Credit	25% to <50% of Credit	50% to <100% of Credit	100% of Credit
<$20k	11.5%	79.2%	20.8%	0.0%	0.0%	0.0%
$20-$50k	32.3%	20.9%	44.1%	26.3%	8.6%	0.0%
$50-$75k	18.0%	0.5%	7.4%	26.8%	50.2%	15.0%
$75-$100k	14.0%	0.0%	0.2%	3.1%	49.6%	47.1%
$100-$150k	14.4%	0.0%	0.0%	0.0%	1.4%	98.6%
$150k+	9.8%	0.0%	0.0%	0.0%	0.0%	100.0%

Table 7 – Georgia Incentive Eligibility by Household Income

Income	% HH	% of Households Observed by Georgia Credit Eligibility				
		No Credit	0% to <25% of Credit	25% to <50% of Credit	50% to <100% of Credit	100% of Credit
<$20k	11.5%	11.0%	57.5%	0.0%	31.5%	0.0%
$20-$50k	32.3%	0.0%	0.0%	6.2%	22.4%	71.4%
$50-$75k	18.0%	0.0%	0.0%	0.0%	0.0%	100.0%
$75-$100k	14.0%	0.0%	0.0%	0.0%	0.0%	100.0%
$100-$150k	14.4%	0.0%	0.0%	0.0%	0.0%	100.0%
$150k+	9.8%	0.0%	0.0%	0.0%	0.0%	100.0%
Income	% HH	% of Households Observed by Georgia Credit Eligibility				
		No Credit	0% to <25% of Credit	25% to <50% of Credit	50% to <100% of Credit	100% of Credit
<$20k	11.5%	17.0%	55.7%	0.0%	27.2%	0.0%
$20-$50k	32.3%	0.0%	0.0%	9.5%	17.3%	73.2%
$50-$75k	18.0%	0.0%	0.0%	0.0%	0.0%	100.0%
$75-$100k	14.0%	0.0%	0.0%	0.0%	0.0%	100.0%
$100-$150k	14.4%	0.0%	0.0%	0.0%	0.0%	100.0%
$150k+	9.8%	0.0%	0.0%	0.0%	0.0%	100.0%

BEV Incentives and Distributive Justice by Race

A similar federal and state tax incentive distributional assessment was performed across race, again using the data in the Epsilon demographic database. Census-based clusters were formed for households from the Epsilon coding. Households were coded as Asian when head of household was identified as Far Eastern, Southeast Asia, and Central and Southwest Asia. Households were coded as White when head of household was identified as Western European, Eastern European, Scandinavian, Jewish, Middle Eastern, and Mediterranean. Households were coded as Other when head of household was identified as Native American, Polynesian, Other, or Uncoded. This resulted in a racial distribution for the Atlanta Metro Area for the purpose of these analyses as 67.7% White, 21.2% Black, 6.4% Hispanic, 4.5% Asian, and 0.2% Other.

Table 8 presents the eligibility for the $7,500 federal tax incentive. With respect to race, only 20.2% of Black households and 29.1% of Hispanic households would qualify to receive the entire federal tax credit; whereas, about 42.1% of White households and 57.4% of Asian households would qualify to receive the entire federal tax credit. Again, the race disparity with respect to qualification for federal tax incentives benefits is significant and striking. Higher income households qualify for the majority of the credits. But, the disparity is not surprising, given that income is highly correlated with race in the metro area. With respect to the Environmental Justice in public policy, however, there are no significant negative environmental consequences associated with the distribution of the incentives across race. Under the Executive Order on environmental justice, there is no disproportional negative impact on lower income groups that needs to be addressed.

With respect to the $5000 Georgia Tax credit, which is spread over a five-year deduction period, and which is not reduced by taking child tax credits, a significantly higher percentage of Black and Hispanic households qualified for the state tax credit than for the federal tax credit. Table 9 presents the eligibility for Georgia state tax incentives based upon the Epsilon demographic database. With respect to race, 65.5% of Black households and 73.5% of Hispanic households would qualify to receive the entire Georgia tax credit; whereas, about 83.5% of White households and 89.7% of Asian households would qualify to receive the entire Georgia tax credit. The racial disparity with respect to qualification for, and potential receipt of Georgia tax incentives benefits is much, much lower than for the federal tax credit. In fact, the Georgia tax credit was much more egalitarian across race than is the federal tax credit. With respect to the Environmental Justice in public policy, as noted previously, there are no significant negative environmental consequences associated with the distribution of incentives and no disproportional negative impact on lower income groups to address. The federal BEV incentive programs do not discriminate based on race. However, the income-based criteria used in the federal incentive, coupled with the fact that a significantly higher percentage Black and Hispanic households are lower income, results in a much lower accessibility for Black and Hispanic households to the federal incentives. Given the fact that the Georgia incentives were much more accessible to Black and Hispanic households, it seems that revisiting the structure of the federal incentive policy would be worthwhile, perhaps aligning the Federal program structure with that of Georgia.

Table 8 – Federal Incentive Eligibility by Race

Race	% HH	% of Households Observed by Federal Credit Eligibility				
		No Credit	0% to <25% of Credit	25% to <50% of Credit	50% to <100% of Credit	100% of Credit
White	67.7%	9.4%	15.2%	13.3%	19.4%	42.8%
Black	21.2%	20.2%	24.6%	16.9%	17.6%	20.8%
Hispanic	6.4%	12.0%	22.6%	16.6%	19.7%	29.1%
Asian	4.5%	4.0%	10.2%	10.5%	17.9%	57.4%
Other	0.2%	10.2%	17.7%	13.3%	19.1%	39.7%
Race	**% Pop.**	**% of Population Observed by Federal Credit Eligibility**				
		No Credit	**0% to <25% of Credit**	**25% to <50% of Credit**	**50% to <100% of Credit**	**100% of Credit**
White	70.7%	9.9%	13.4%	11.8%	19.4%	45.5%
Black	19.3%	21.6%	21.7%	15.4%	18.8%	22.6%
Hispanic	5.6%	13.7%	19.4%	14.6%	20.4%	31.8%
Asian	4.1%	4.9%	9.2%	9.4%	18.0%	58.6%
Other	0.2%	10.5%	15.6%	11.7%	19.2%	43.0%

Table 9 – Georgia Incentive Eligibility by Race

Race	% HH	% of Households Observed by Georgia Credit Eligibility				
		No Credit	0% to <25% of Credit	25% to <50% of Credit	50% to <100% of Credit	100% of Credit
White	67.7%	1.1%	4.9%	2.0%	8.5%	83.5%
Black	21.2%	2.1%	12.8%	2.5%	17.2%	65.5%
Hispanic	6.4%	0.6%	7.3%	1.6%	17.0%	73.5%
Asian	4.5%	0.2%	2.1%	1.0%	6.9%	89.7%
Other	0.2%	1.2%	5.7%	1.8%	11.4%	79.8%
Race	**% Pop.**	**% of Population Observed by Georgia Credit Eligibility**				
		No Credit	**0% to <25% of Credit**	**25% to <50% of Credit**	**50% to <100% of Credit**	**100% of Credit**
White	70.7%	1.1%	3.2%	2.5%	5.2%	88.0%
Black	19.3%	2.5%	9.4%	3.4%	12.3%	72.3%
Hispanic	5.6%	0.7%	5.4%	2.4%	11.7%	79.8%
Asian	4.1%	0.3%	1.5%	1.6%	4.5%	92.1%
Other	0.2%	1.2%	4.1%	2.3%	7.1%	85.4%

Conclusions

Over the last decade, the federal government and 24 state governments have offered PEV purchase incentives to help consumers overcome the market barrier of initial purchase cost (higher PEV purchase costs compared to their conventional gasoline equivalents). This research investigated the potential equity issue of federal-level and state-level PEV income tax credits implemented in the United States, including federal PEV tax credit, and state income tax credit implemented in Georgia, South Carolina, Utah, Louisiana, and Montana. By quantifying the tax credit eligibility for 2.1 million households in the Metro Atlanta area, the research identified the distribution of benefits associated with consumption of PEV incentives across demographic groups in the Metro Atlanta area. The research team collected license plate data from Atlanta freeways during the morning and afternoon peak commute periods, matched with vehicle make, model, and model year information to compare the air pollutant and greenhouse gases (GHGs) emissions rates across household groups as an indication of potential environmental benefits experienced from replacing existing conventional vehicles with battery electric vehicles.

To quantify the credit eligibility from federal and state tax liability, the research team verified the tax estimation equations using TurboTax federal and state software for each scenario. Through the exploration of 2018 federal tax policies, the research prepared graphs showing the income threshold and federal credit eligibility for households in the three most common tax filing status categories: Single (S), Married Filing Jointly (MJ), and Head of Household (HH). Analytical results revealed that credit eligibility varies significantly depending on the filing status, household income, and number of children. The federal income tax credit is only worth $7,500 to those households whose federal tax liability at the end of the year is $7,500 or more. Low income households and households with children (who already receive child tax credit reductions that are counted first, before PEV deductions are applied) are less likely to receive the full (or any) federal tax credit. Households with higher income and fewer children are therefore more likely to be eligible for a greater share of the federal PEV credit. For example, the income threshold for a household with single filing status to receive the full federal PEV incentive is $64,600 per year if they have no children and $75,000 per year if they have four children. The threshold range is $89,700-$106,000 for married filing jointly (MJ) households, and $77,000-$88,000 for head of household (HH) filing status. The income range that qualifies for only 50% of federal PEV credit ranges from $44,900 (for households with zero children) to $58,500 (for households with four children) for single filing status, $58,400-$78,500 for married filing jointly status, and $51,500-$70,100 for head of household filing status.

State credits can be classified into two groups: Group 1 includes Georgia, South Carolina, and Utah, where the state income tax and credits are independent of federal tax liability. Depending on the filing status, credit eligibility of states in Group 1 increases with household income level. Also, states with higher EV credit values and lower state tax rates (corresponding to lower tax liability, or less tax deduction to be used for EV credit) require a higher income threshold for credit eligibility. It is important to note that Georgia policy allows the Georgia tax credit to be carried forward for up to five tax years, with a maximum annual credit of $1,000, making the income threshold for the $5,000 credit in Georgia ($24,800) lower than the threshold for the $1,500 credit in Utah ($31,000) and the $2,000 credit in South Carolina ($46,500). The credit calculation for states in Group 2 (Louisiana and Montana) are more complicated because they involve a federal non-refundable tax liability deduction. These states essentially require payment of state taxes on any federal credit received. Hence, the state income tax credit depends on federal tax liability, and the number of children, and the amount of federal credit received. Unlike the federal credit and Group 1 state credits, households with high income are not fully eligible for state credit in Louisiana, and interestingly, are required to pay a few dollars more in Montana, a policy which provides a small disincentive for PEV purchase.

The research employed household-level demographic data in the Metro Atlanta area licensed from a marketing firm to identify the impact of PEV eligibility in the Atlanta Metro area, including the 2.1 million households and 4.47 million populations that falls into various credit eligibility levels. The results show that about 33.5% of single households are eligible for full federal $7,500 credit, and this value is significantly higher (43.9%) for households under the married filing jointly status, indicating higher tax liability for married families that can be used for PEV credit. In contrast, only 22.3% of households with head of household tax filing status have access to the entire credit. In summary, 62.1% of households (59.2% of the population) in surveyed households are not eligible for full federal PEV credit, and 43.2% of households (39.9% of population) are eligible for less than 50% of credit ($3,750). There are significantly more households (80%) and population (85%) that are eligible for the full $5,000 Georgia state credit. This results from the state policy that allocates the $5,000 Georgia tax credit at $1,000 for each year over the five years following the purchase of the vehicle.

The research team also used license plate data collected in the field and matched with demographic information to compare the air pollutant and greenhouse gases (GHGs) emissions rates estimated using MOVES-Matrix across household groups as an indication of potential environmental benefits experienced from replacing existing conventional vehicles with battery electric vehicles. From the license plate data analysis, households with lower income tend to own older vehicles. Analyses in the previous chapters found that lower income households face greater barriers to obtaining credits when purchasing EVs; however, the age distribution of the fleet in the figures indicates that replacing older vehicles in these lower income households with EVs will yield larger energy reduction and environmental benefits. Analyses also indicate that 83.1% of households that own BEVs were likely eligible for full $7,500 credit, which is much higher than that of the Atlanta average (37.9%) and much higher than the percentage of households that own no BEVs (49.4%). From the emission analysis, vehicles from households with lower income levels produce higher emissions (including CO, NOx, VOC, GHGs and PM2.5) and would provide greater emission reduction benefits and energy savings if they were replaced with BEVs, assuming that daily vehicle use is comparable. For example, vehicles from households with no federal credit eligibility produces 54.79% higher NOx emissions than households with 100% credit eligibility in per miles running under FTP cycle operation. This also indicate that if the PEV credits could get t households with older vehicles, they may provide significant and efficient emissions reductions

In general, low income households do not have comparable accessibility to federal and state PEV incentives as do high income households. None of the households earning less than $50k/year, and only 27% of the households earning between $50k/year and $75k per year would qualify to receive the entire federal tax credit. Whereas, more than 99.5% of the households earning more than $100k/year (24.1% of all metro area households) qualify for the entire federal tax credit. In contrast, with respect to the $5000 Georgia Tax credit, which is spread over a five-year deduction period, and which is not reduced by taking child tax credits, a significantly higher percentage of lower income Georgia households qualified for the state tax credit than for the federal tax credit; 100% of the households earning more than $25k/year qualify to receive the entire Georgia tax credit. Only about 1.3% of metro area households were not eligible to receive any credit at all, and only about 6.6% were eligible to receive less than 25% of the credit (all of these households earned less than $20k/year). Whereas, 100% of the households earning more than $50k/year and 79.3% of all households in the metro area qualified for the entire state tax credit. The income disparity with respect to qualification for, and potential receipt of Georgia tax incentives benefits is much lower than for the federal tax credit. A similar federal and state tax incentive distributional assessment was performed across race, again using the data in the Epsilon demographic database. The results show that only 20.2% of Black households and 29.1% of Hispanic households would qualify to receive the entire federal tax credit; whereas, about 42.1% of White households and 57.4% of Asian households would qualify to receive the entire federal tax credit. The race disparity with respect to qualification for federal tax incentives benefits is significant and striking; a result of the correlation of race and income in the metro Atlanta area. A significantly higher percentage of Black and Hispanic households qualified for the Georgia state tax credit than for the federal tax credit. About 65.5% of Black households and 73.5% of Hispanic households would qualify to receive the entire Georgia tax credit; whereas, about 83.5% of White households and 89.7% of Asian households would qualify to receive the entire Georgia tax credit.

With respect to the Environmental Justice in public policy, there are no significant negative environmental consequences associated with the distribution of incentives and no disproportional negative impact on lower income groups to address. The income-based criteria used in the federal incentive, coupled with the fact that a significantly higher percentage Black and Hispanic households are lower income, results in a much lower accessibility for Black and Hispanic households to the federal incentives. Given the fact that the Georgia incentives were much more accessible to Black and Hispanic households, it seems that revisiting the structure of the federal incentive policy would be worthwhile, perhaps aligning the Federal program structure with that of Georgia.

The study findings are expected to help decision-makers identify any potential distributive justice issues concealed within existing incentive policies. For example, BEV incentive policies do not need to be this complex with respect to tax deductions and credits. This also makes it difficult for customers to know whether they will obtain the (full) credit when you are purchasing the PEV. Obtaining only a percent of a credit after a purchase could be very disappointing, which is an issue more likely to happen in federal incentive program and in some states as well. The researchers recommend that "competition" between BEV and child tax credits be removed from federal policy. Households with lower income and households with children are more likely to place a greater value on the incentive in their PEV purchase decisions. The GA policy that spreads tax credits over a five-year period also seems appropriate and should be considered at national level. As a more progressive approach, PEV incentives can be designed to be independent of tax filing status, household income (which is also correlated to race), and number of children. Instead, to achieve greater energy savings and environmental benefits, policies should probably target incentives to households with high-mileage vehicles (and older commute vehicles) so that society can obtain get the largest reduction in fuel use and emissions per vehicle for every dollar of incentive spent. Based on the findings, future efforts can be put to identify the potential PEV purchase incentives that could be implemented that might provide additional energy saving and emissions reductions designed to enhance the distributional benefits to minority, low-income, disability, and other potentially underserved communities that may not have benefitted as much from traditional incentive programs.

It is important to remind readers of the limitations of this research. First of all, we used median value of income class as the indicator of the household income (example, $62.5k for income $60-65k/year class, and $67.5k for income $65-70k/year class), which introduces some uncertainty, although the $5k-bin classification is small. There are also a variety of additional credits that many households may qualify to receive (e.g., legally blind, military service, and disabled dependent credits), and large itemized deductions to income that may apply to some households (e.g., state and local taxes, mortgage interest, extraordinary medical expenses, etc.); these credits and deductions were not included in this analysis. We are also not able to determine the impact of households' awareness of their credit eligibility. All these factors make it is difficult to verify what percent credit consumption actually occurred across income groups. Also, it is important to note that the sampled households from license plate collection and matching process do not provide an unbiased representation of the Atlanta demographics. The license plates were collected in freeway observation, which is assumed to be high-mileage vehicles but younger fleet than Atlanta average (purposefully performed so that we could compare commuting activity). The license plate data for vehicle age distribution and emissions analysis has some accuracy issues: the research team does not have access to the actual annual mileage for any vehicle or household information, which is required for total emission estimation in household level, not to mention the uncertainty from the lack of operating speed in energy and emissions modeling. Nevertheless, this research identifies some clear and important differences in PEV credit accessibility, not likely to be significantly affected by these limitations, that should be revisited explicitly when new federal and state PEV credit programs are designed and implemented.

References

AFDC, Alternative Fuels Data Center, 2020. State Laws and Incentives. Available at: https://afdc.energy.gov/laws/state [Accessed May 2020]

Axsen, J., Goldberg, S. and Bailey, J., 2016. How might potential future plug-in electric vehicle buyers differ from current "Pioneer" owners? *Transportation Research Part D: Transport and Environment*, *47*, pp.357-370.

Bills, T.S., Sall, E.A. and Walker, J.L., 2012. Activity-based travel models and transportation equity analysis: Research directions and exploration of model performance. *Transportation Research Record*, *2320*(1), pp.18-27.

Beresteanu, A. and Li, S., 2011. Gasoline Prices, Government Support, and The Demand for Hybrid Vehicles in The United States. *International Economic Review*, 52(1), pp.161-182.

Carley, S., Krause, R.M., Lane, B.W. and Graham, J.D., 2013. Intent to purchase a plug-in electric vehicle: A survey of early impressions in large US cites. *Transportation Research Part D: Transport and Environment*, *18*, pp.39-45.

Chandra, A., Gulati, S. and Kandlikar, M., 2010. Green Drivers or Free Riders? An Analysis of Tax Rebates for Hybrid Vehicles. *Journal of Environmental Economics and Management*, 60(2), pp.78-93.

Diamond, D., 2009. The Impact of Government Incentives for Hybrid-Electric Vehicles: Evidence from US States. *Energy Policy*, *37*(3), pp.972-983.

EIA, Energy Information Administration, 2020. U.S. Households Are Holding on to Their Vehicles Longer. Available at: https://www.eia.gov/todayinenergy/detail.php?id=36914 [Accessed May 2020]

Gallagher, K. S. and Muehlegger, E. 2011. Giving Green to Get Green? Incentives and Consumer Adoption of Hybrid Vehicle Technology. *Journal of Environmental Economics and Management*, 61(1), pp.1-15.

Gao, O.H. and Klein, R.A., 2010. Environmental equity in participation of the clean air school bus program: The case of New York state. *Transportation Research Part D: Transport and Environment*, *15*(4), pp.220-227.

Georgia DOR, Georgia Department of Revenue, 2020. Individual Taxes. Available at: https://dor.georgia.gov/taxes/individual-taxes. [Accessed May 2020]

IRS, Internal Revenue Service, 2020. Tax Information for Individuals. Available at: https://www.irs.gov/individuals [Accessed May 2020]

Jenn, A., Springel, K. and Gopal, A.R., 2018. Effectiveness of Electric Vehicle Incentives in The United States. *Energy Policy*, *119*, pp.349-356.

Jin, L., Searle, S., and Lutsey, N. 2014. Evaluation of State-Level U.S. PEV Incentives. International Council on Clean Transportation. Available at: http://www.theicct.org/sites/default/files/publications/ICCT_state-EVincentives_20141030.pdf [Accessed May 2020]

Kodjak, D., 2012. Consumer Acceptance of Electric Vehicles In the US. *USA: The International Council for Clean Transportation*. Mobile Source Technical Review Subcommittee. Available at: https://www.epa.gov/sites/production/files/2014-09/documents/kodjak121312.pdf, [Accessed May 2020]

Liu, H., Xu, Y., Rodgers, M.O., and Guensler, R. 2015. Developing Vehicle Classification Inputs for Project-Level MOVES Analysis. Transportation Research Record, 2503(1), 81-90.

Liu, H., Xu, X., Rodgers, M. O., Xu, Y. A. and Guensler, R. L. 2017. MOVES-Matrix and Distributed Computing for Microscale Line Source Dispersion Analysis. *Journal of the Air & Waste Management Association,* 67(7), 763-775.

Liu, H., Guensler, R., Lu, H., Xu, Y., Xu, X. and Rodgers, M.O., 2019. MOVES-Matrix for High-Performance On-Road Energy and Running Emission Rate Modeling Applications. *Journal of the Air & Waste Management Association*, 69(12), pp.1415-1428.

Miller, M. 2018. Rethinking Electric Vehicle Incentives. University of Colorado Law School. Available at: https://www.colorado.edu/law/sites/default/files/attached-files/miller_online_copy.pdf [Accessed May 2020]

Montana DOR, Montana Department of Revenue, 2020. Individual Income Tax. Available at: https://mtrevenue.gov/taxes/individual-income-tax/ [Accessed May 2020]

Sheldon, T.L., DeShazo, J.R., and Carson, R.T., 2017. Designing Policy Incentives for Cleaner Technologies: Lessons from California's Plug-In Electric Vehicle Rebate Program. *Journal of Environmental Economics and Management*, 84, pp.18-43.

South Carolina DOR, South Carolina Department of Revenue. Individual Income Tax. Available at: https://dor.sc.gov/tax/individual-income/forms [Accessed May 2020]

Sovacool, B.K., Kester, J., Noel, L. and de Rubens, G.Z., 2018. The Demographics of Decarbonizing Transport: The Influence of Gender, Education, Occupation, Age, and Household Size On Electric Mobility Preferences in The Nordic Region. *Global Environmental Change*, *52*, pp.86-100.

USEPA, U.S. Environmental Protection Agency. 2015a. MOVES2014a. Available at: https://www3.epa.gov/otaq/models/moves/ [Accessed April 2020].

USEPA. U.S. Environmental Protection Agency. 2015b. Transportation Conformity Guidance for Quantitative Hot-Spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas. EPA Report EPA-420-B-15-084. Available at: https://www.epa.gov/state-and-local-transportation/project-level-conformity-and-hot-spot-analyses [Accessed April 2020].

USEPA. U.S. Environmental Protection Agency. 2019. Office of Transportation and Air Quality. Light-Duty Vehicle and Engine Emission Certification. Available at: https://www.epa.gov/ve-certification/overview-certification-and-compliance-vehicles-and-engines#copy [Accessed April 2020].

Utah State Tax Commission, 2020. Official Utah Income Tax Information. Available at: https://incometax.utah.gov/ [Accessed May 2020]

Vallamsundar, S. and Lin, J., 2012. MOVES and AERMOD used for PM2.5 Conformity hot spot air quality modeling. Transportation Research Record: Journal of the Transportation Research Board. 2270, 39-48. DOI: https://doi.org/10.3141/2270-06

Vergis, S. and Chen, B., 2015. Comparison of Plug-In Electric Vehicle Adoption in the United States: A State by State Approach. *Research in Transportation Economics*, *52*, pp.56-64.

Wee, S., Coffman, M. and La Croix, S., 2018. Do Electric Vehicle Incentives Matter? Evidence from the 50 US States. *Research Policy*, 47(9), pp.1601-1610.

Xu, X., Liu, H., Anderson, J. M., Xu, Y., Hunter, M. P., Rodgers, M. O., and Guensler, R. L. 2016. Estimating Project-Level Vehicle Emissions with VISSIM and MOVES-Matrix. *Transportation Research Record*, 2570(1), 107-117.

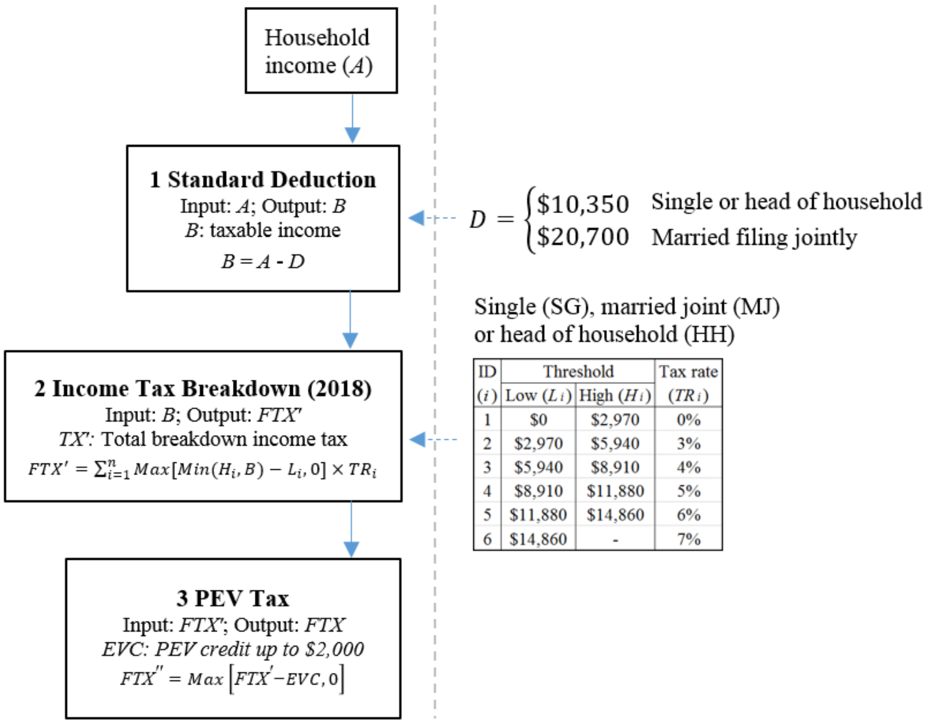
Xu, Y., Liu, H., Rodgers, M. O., Guin, A., Hunter, M., Sheikh, A., & Guensler, R. 2017. Understanding the Emission Impacts of High-Occupancy Vehicle (HOV) to High-Occupancy Toll (HOT) Lane Conversions: Experience from Atlanta, Georgia. *Journal of the Air & Waste Management Association*, 67(8), 910-922.

Zambrano-Gutiérrez, J.C., Nicholson-Crotty, S., Carley, S. and Siddiki, S., 2018. The Role of Public Policy in Technology Diffusion: The Case of Plug-In Electric Vehicles. *Environmental Science & Technology*.

Zhou, Y., Santini, D.J., Vasquez, K., and Rood, M. 2017. *Contributing Factors in Plug-in Electric Vehicle Adoption in the United States: A Metro/County Level Investigation*. Paper 17-05472 presented at the Transportation Research Board 96th Annual Meeting, January, Washington, DC.

Appendices

Appendix 1: Data Flow of 2018 Income Tax Estimation for South Carolina and Utah



ID (i)	Threshold Low (L_i)	Threshold High (H_i)	Tax rate (TR_i)
1	$0	$2,970	0%
2	$2,970	$5,940	3%
3	$5,940	$8,910	4%
4	$8,910	$11,880	5%
5	$11,880	$14,860	6%
6	$14,860	-	7%

Figure A-1: Data Flow of South Carolina State Income Tax Estimation in 2018 (South Carolina, 2020)

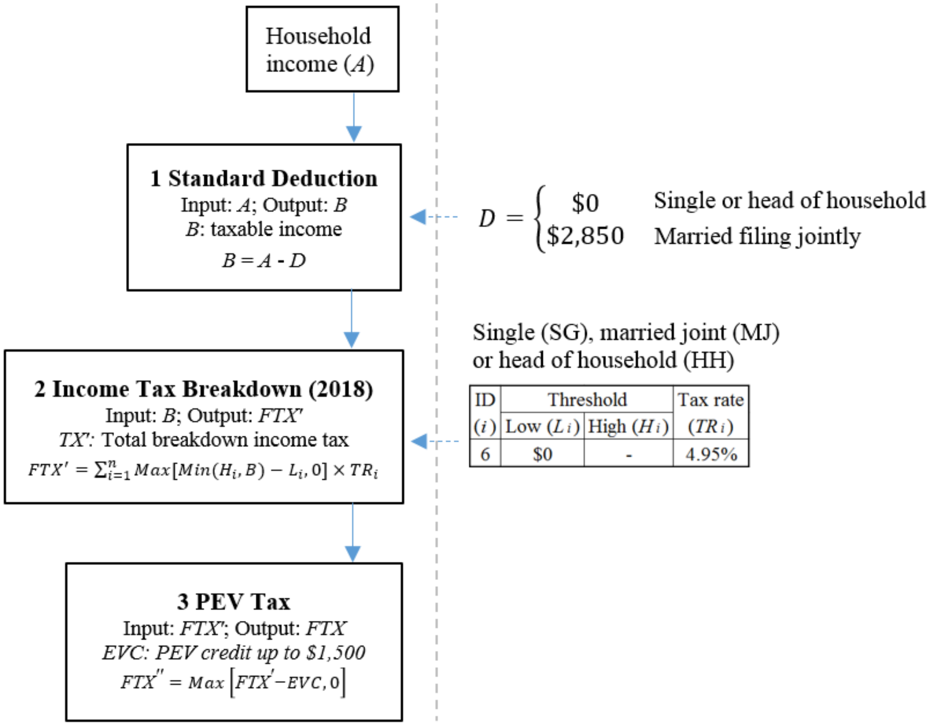
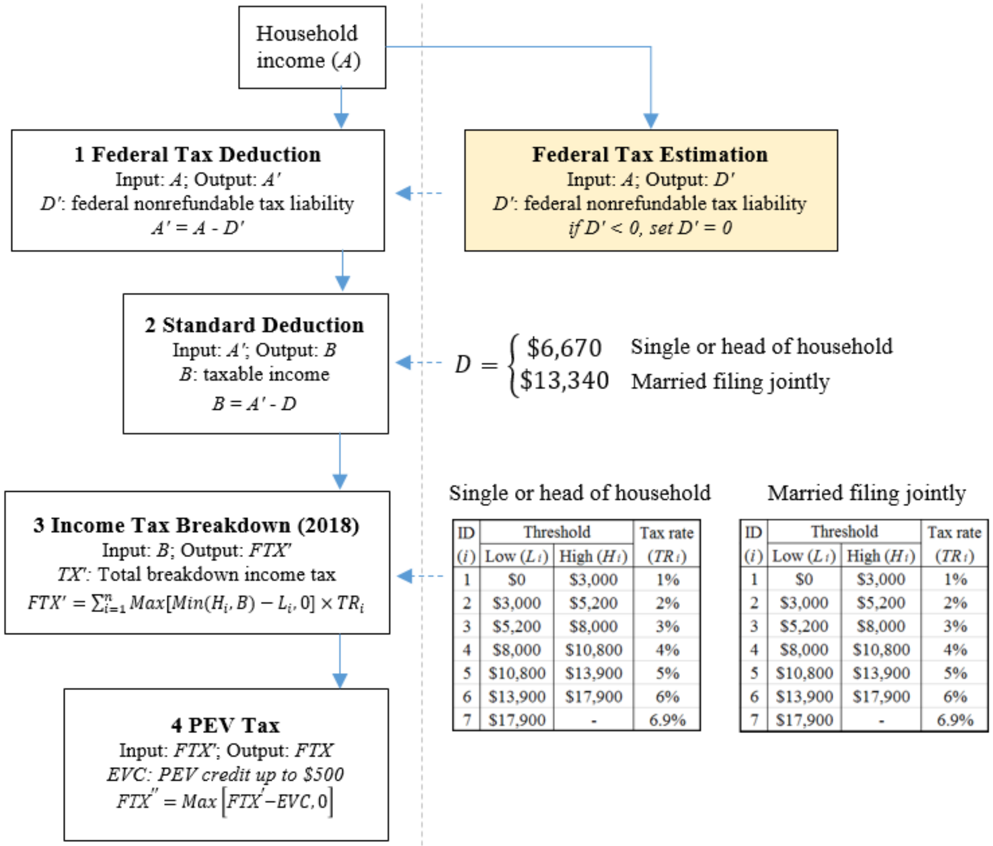


Figure A-2: Data Flow of Utah State Income Tax Estimation in 2018 (Utah State Tax Commission, 2020)



Single or head of household

ID (i)	Threshold Low (L_i)	Threshold High (H_i)	Tax rate (TR_i)
1	\$0	\$3,000	1%
2	\$3,000	\$5,200	2%
3	\$5,200	\$8,000	3%
4	\$8,000	\$10,800	4%
5	\$10,800	\$13,900	5%
6	\$13,900	\$17,900	6%
7	\$17,900	-	6.9%

Married filing jointly

ID (i)	Threshold Low (L_i)	Threshold High (H_i)	Tax rate (TR_i)
1	\$0	\$3,000	1%
2	\$3,000	\$5,200	2%
3	\$5,200	\$8,000	3%
4	\$8,000	\$10,800	4%
5	\$10,800	\$13,900	5%
6	\$13,900	\$17,900	6%
7	\$17,900	-	6.9%

Figure A-3: Data Flow of Montana State Income Tax Estimation in 2018 (Montana DOR, 2020)

Appendix 2: Summary of Atlanta Demographic Data

Household Income

Annual Income ($)	Number of Households	Percentage
0-15K	145,827	6.86%
15-20K	96,822	4.56%
20-25K	180,519	8.49%
25-30K	43,757	2.06%
30-35K	164,638	7.75%
35-40K	44,163	2.08%
40-45K	89,156	4.19%
45-50K	164,693	7.75%
50-55K	34,185	1.61%
55-60K	63,006	2.96%
60-65K	65,249	3.07%
65-70K	84,648	3.98%
70-75K	136,148	6.41%
75-80K	57,100	2.69%
80-85K	42,806	2.01%
85-90K	58,004	2.73%
90-95K	56,992	2.68%
95-100K	83,425	3.93%
100-105K	27,636	1.30%
105-110K	19,548	0.92%
110-115K	22,495	1.06%
115-120K	30,213	1.42%
120-125K	35,004	1.65%
125-130K	30,915	1.45%
130-135K	32,213	1.52%
135-140K	29,027	1.37%
140-145K	32,376	1.52%
145-150K	45,835	2.16%
150-160K	9,783	0.46%
160-170K	20,311	0.96%
170-175K	31,934	1.50%
175-190K	33,313	1.57%
190-200K	31,430	1.48%
200-225K	29,811	1.40%
225-250K	30,184	1.42%
>250K	22,222	1.05%

Number of Children

Number of Children	Number of Households	Percentage
0	1,735,288	81.65%
1	206,742	9.73%
2	74,274	3.49%
3	44,351	2.09%
4	29,284	1.38%
5	18,236	0.86%
6	10,176	0.48%
7	4,738	0.22%
8	1,703	0.08%
9	596	0.03%

Number of Adults

Number of Adults	Number of Households	Percentage
1	943,358	44.39%
2	916,399	43.12%
3	191,895	9.03%
4	57,815	2.72%
5	15,921	0.75%

Married Status

Marriage	Number of Households	Percentage
Married	1,020,309	48.01%
Not Married	1,104,515	51.97%

Appendix 3: MOVES VSP/STP Operating Mode Bin Definition

Operating Mode ID	Operating Mode Description	Vehicle Specific Power (VSP)	Vehicle Speed	Vehicle Acceleration
		(KW/tonne)	(v_t, mph)	(a, mph/sec)
0	Deceleration/Braking			$a_t \leq -2.0$ OR ($a_t < -1.0$ AND $a_{t-1} < -1.0$ AND $a_{t-2} < -1.0$)
1	Idle		$-1.0 \leq v_t < 1.0$	Any
11	Coast	$VSP_t < 0$	$0 \leq v_t < 25$	Any
12	Cruise/Acceleration	$0 \leq VSP_t < 3$	$0 \leq v_t < 25$	Any
13	Cruise/Acceleration	$3 \leq VSP_t < 6$	$0 \leq v_t < 25$	Any
14	Cruise/Acceleration	$6 \leq VSP_t < 9$	$0 \leq v_t < 25$	Any
15	Cruise/Acceleration	$9 \leq VSP_t < 12$	$0 \leq v_t < 25$	Any
16	Cruise/Acceleration	$12 \leq VSP_t$	$0 \leq v_t < 25$	Any
21	Coast	$VSP_t < 0$	$25 \leq v_t < 50$	Any
22	Cruise/Acceleration	$0 \leq VSP_t < 3$	$25 \leq v_t < 50$	Any
23	Cruise/Acceleration	$3 \leq VSP_t < 6$	$25 \leq v_t < 50$	Any
24	Cruise/Acceleration	$6 \leq VSP_t < 9$	$25 \leq v_t < 50$	Any
25	Cruise/Acceleration	$9 \leq VSP_t < 12$	$25 \leq v_t < 50$	Any
27	Cruise/Acceleration	$12 \leq VSP_t < 18$	$25 \leq v_t < 50$	Any
28	Cruise/Acceleration	$18 \leq VSP_t < 24$	$25 \leq v_t < 50$	Any
29	Cruise/Acceleration	$24 \leq VSP_t < 30$	$25 \leq v_t < 50$	Any
30	Cruise/Acceleration	$30 \leq VSP_t$	$25 \leq v_t < 50$	Any
33	Cruise/Acceleration	$VSP_t < 6$	$50 \leq v_t$	Any
35	Cruise/Acceleration	$6 \leq VSP_t < 12$	$50 \leq v_t$	Any
37	Cruise/Acceleration	$12 \leq VSP_t < 18$	$50 \leq v_t$	Any
38	Cruise/Acceleration	$18 \leq VSP_t < 24$	$50 \leq v_t$	Any
39	Cruise/Acceleration	$24 \leq VSP_t < 30$	$50 \leq v_t$	Any
40	Cruise/Acceleration	$30 \leq VSP_t$	$50 \leq v_t$	Any

Appendix 4: Average Emission Rates of Conventional Vehicle Owners: by Tax Filing Status, Household Income Level and Number of Children

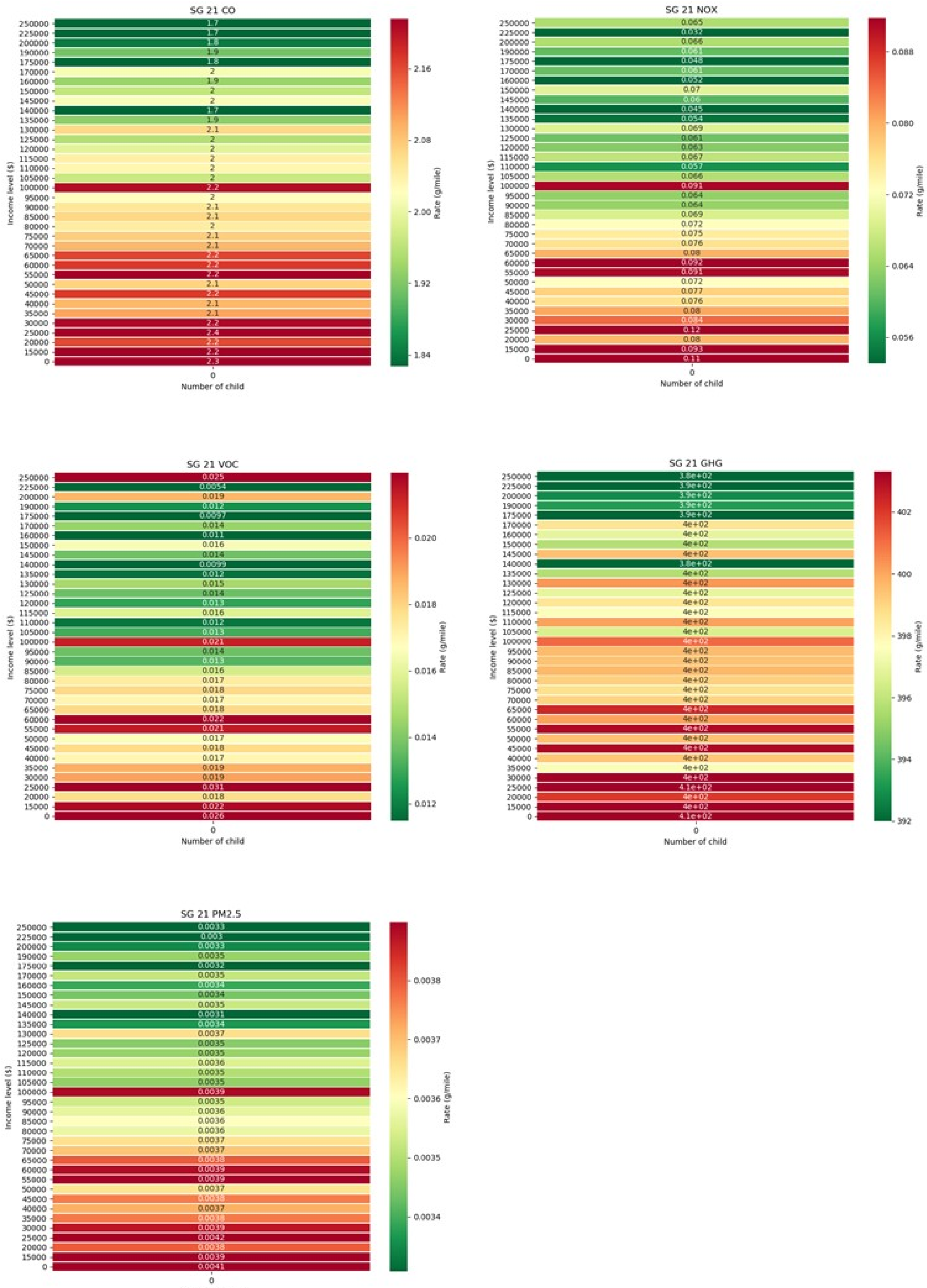


Figure A-4: Vehicle Emission Rates of Single Filing Households: Passenger Car

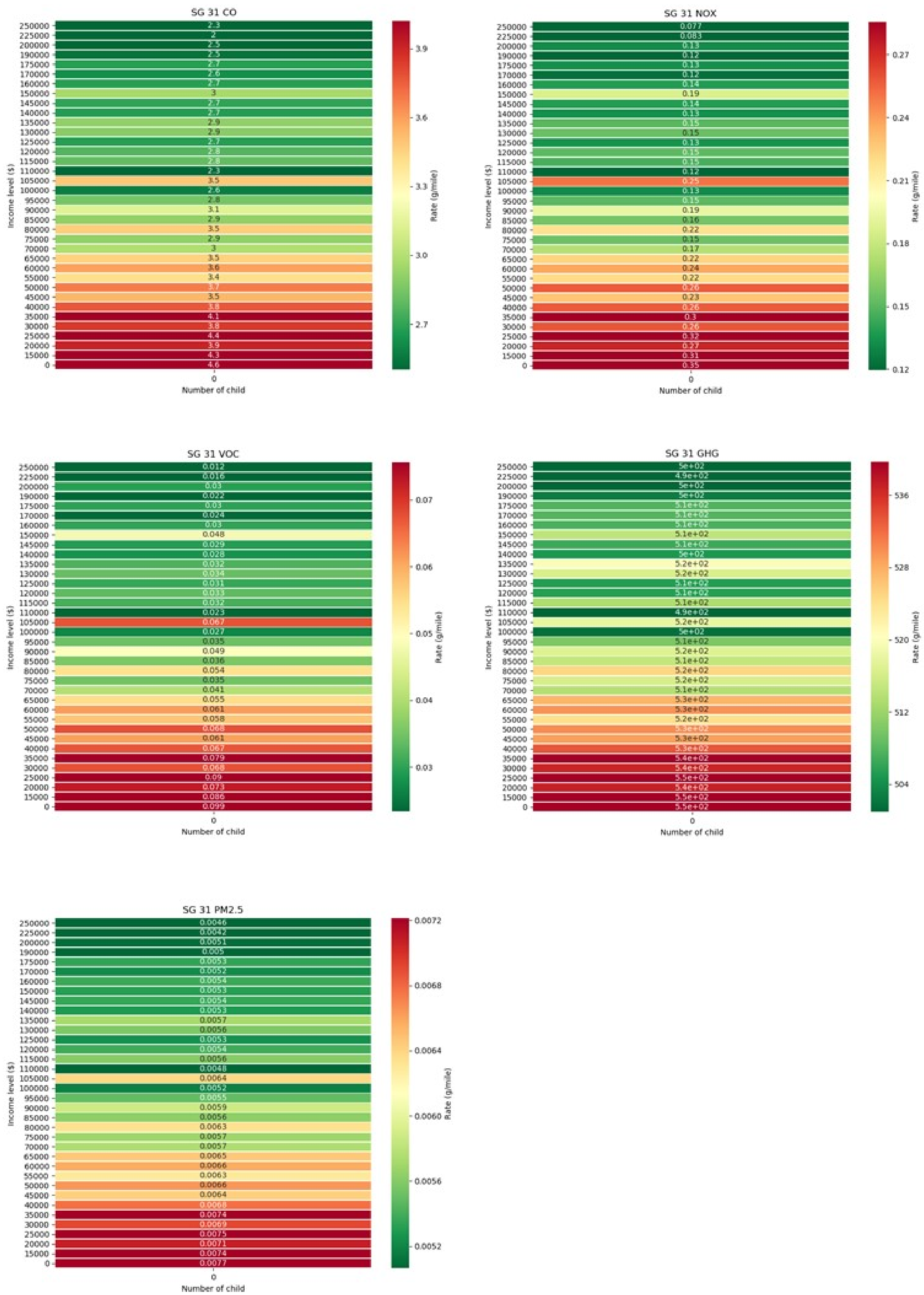


Figure A-5: Vehicle Emission Rates of Single Filing Households: Passenger Truck

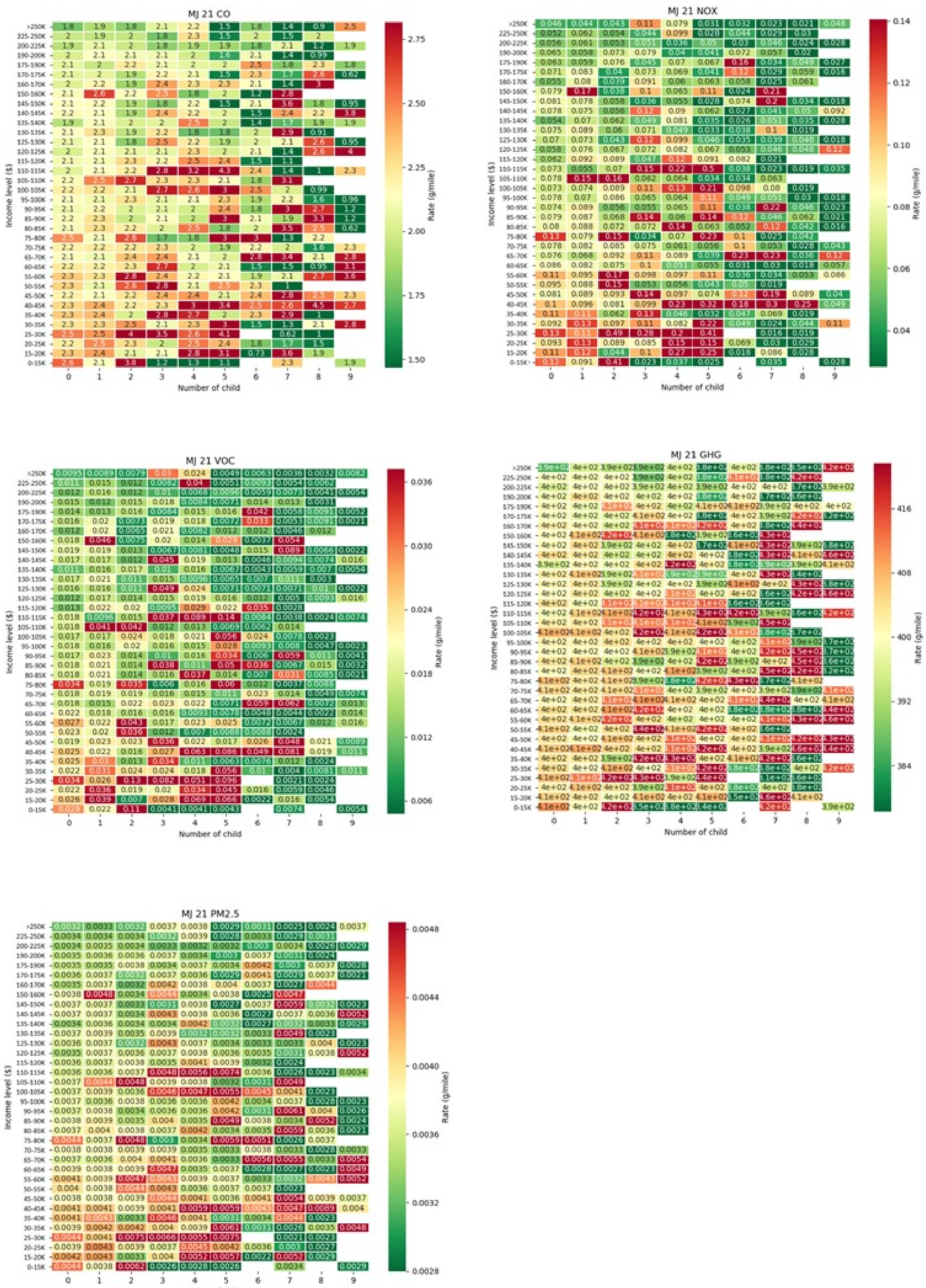


Figure A-6: Vehicle Emission Rates of MJ Filing Households: Passenger Car

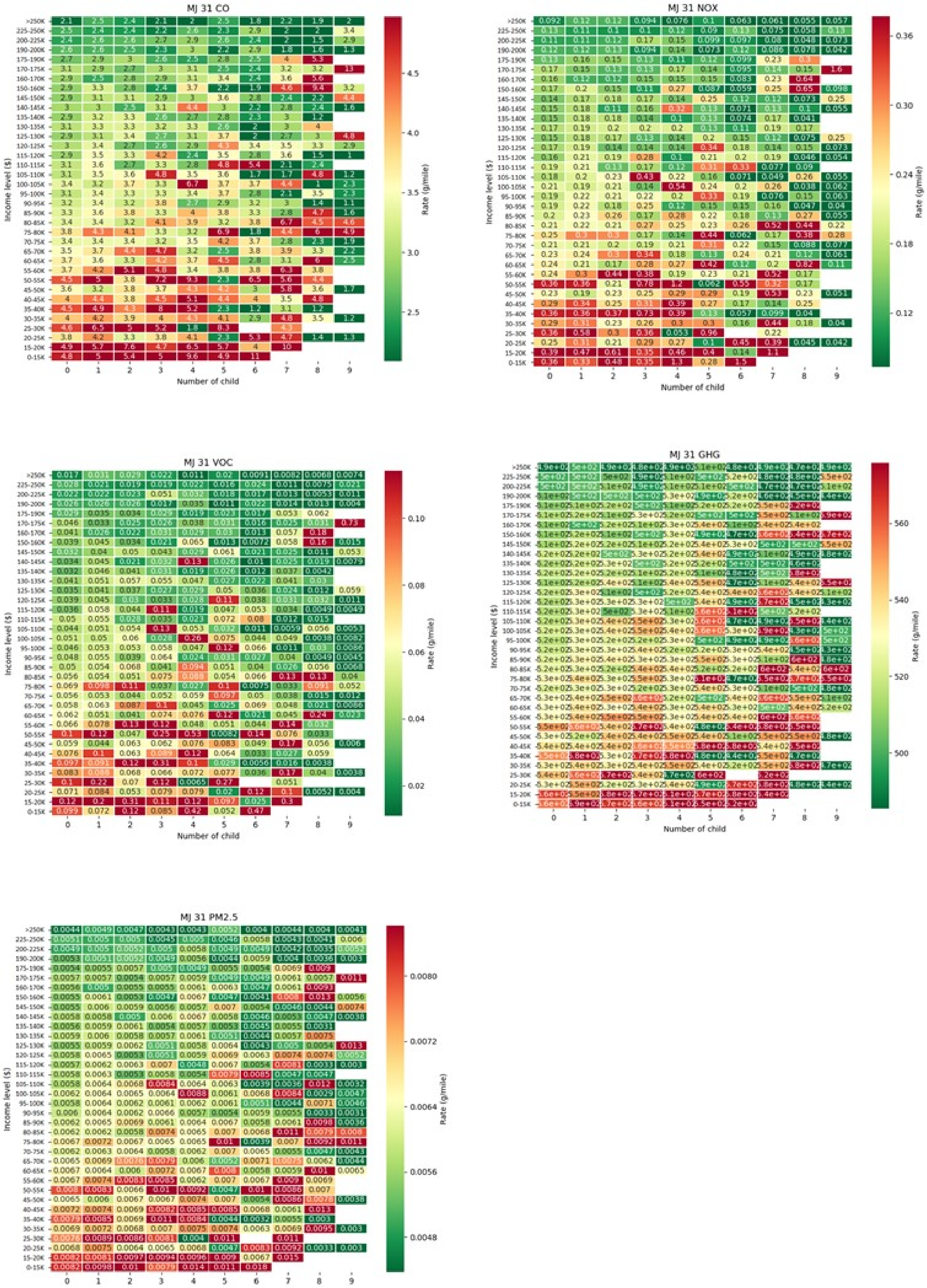


Figure A-7: Vehicle Emission Rates of MJ Filing Households: Passenger Truck

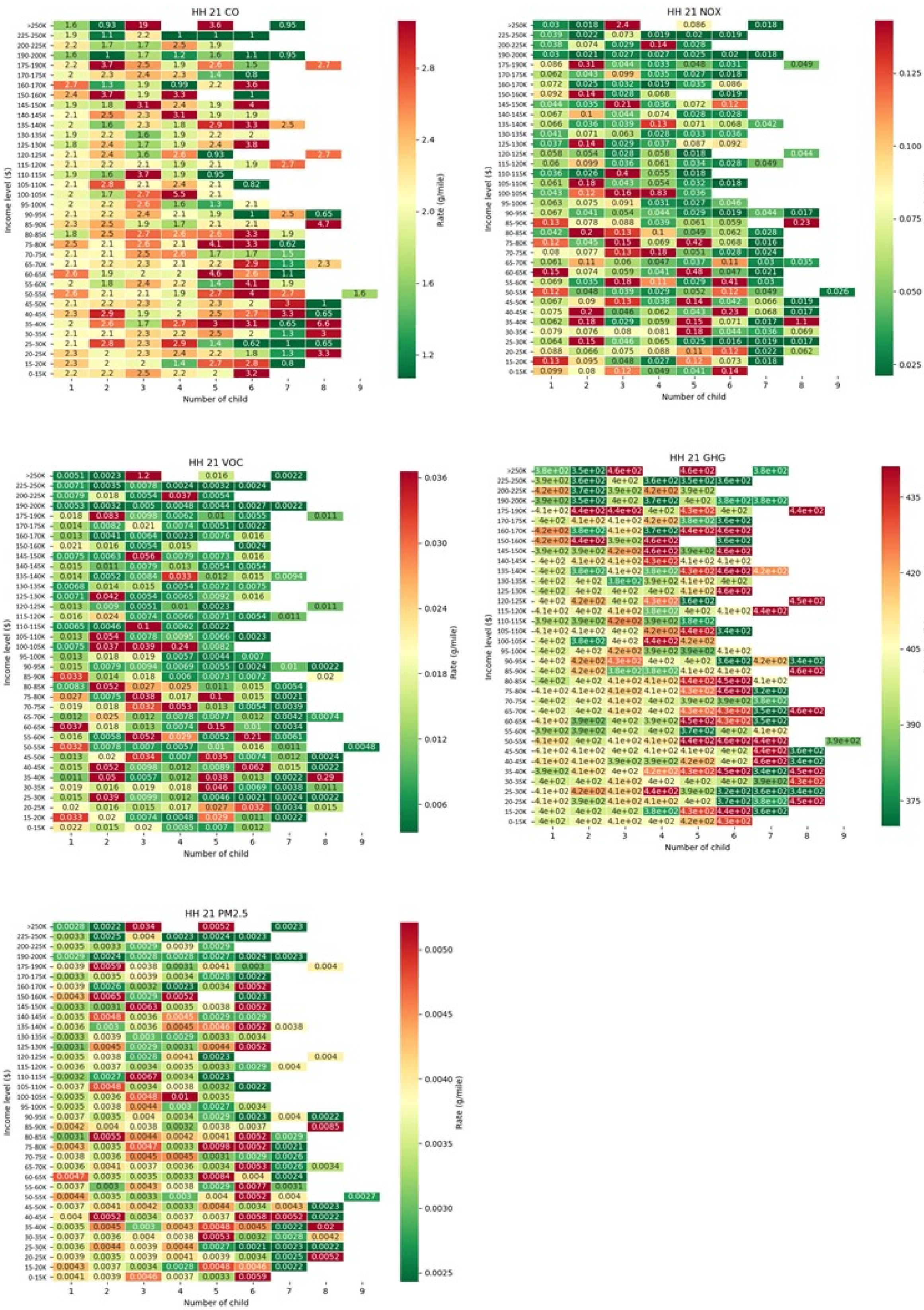


Figure A-8: Vehicle Emission Rates of HH Filing Households: Passenger Car

Figure A-9: Vehicle Emission Rates of HH Filing Households: Passenger Truck

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